Water and Wastewater Operators'

1985 Seminar

Alberta

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Pollution Control Division
Municipal Engineering Branch

1985 ALBERTA OPERATORS SEMINAR

PRESENTATIONS
MADE AT THE
1985
ALBERTA OPERATORS SEMINAR

BANFF PARK LODGE

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INTRODUCTION

The Alberta Water and Wastewater Operators Seminar is an annual updating and general technical information program co-sponsored by the Alberta Water and Wastewater Operators' Association, the Western Canada Water and Sewage Conference, and Alberta Environment. The Seminar is designed to be of interest to treatment plant operators, distribution and collection system operators, and village and town foremen and superintendents. A wide variety of topics relating to water treatment, water distribu- tion, wastewater collection, and wastewater treatment are discussed. Displays set up by equipment and product suppliers provide an opportunity for operators to view the latest in treatment equipment.

This publication is a collection of the presentations made at the seminar in 1985.

The Pollution Control Division of Alberta Environment as well as the co-sponsoring organizations, assume no responsibility for opinions or statements of facts expressed by contributors. Speakers' opinions do not necessarily represent official policy.

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LIST OF SPEAKERS

Dr. Marco Aieta	Technical Director Rio Linda Chemical Company c/o Harrisons & Crosfield Canada Ltd. 5711 - 1 Street, S.E. Calgary, Alberta T2H 1H9
Mr. Steve Blonsky	Superintendent Town of High Prairie Box 179 High Prairie, Alberta T0B 1E0
Mr. John Boll	Field Services Carus Chemical Co. 1500 - 8th Street Lasalle, Illinois, USA 61301
Mr. Jim Burd	Canada/Europe Ford Meter Box Company Inc. P.O. Box 443 Wabash, Indiana, USA
Ms. Elaine Conners	Control & Metering Ltd. Unit 2, 3610 - 29 St., N.E. Calgary, Alberta T1Y 5Z7
Ms. Carol Eamer	Education Officer Education & Program Devpt Branch Occupational Health & Safety Division 5th Floor, 10709 Jasper Avenue Edmonton, Alberta T5J 3N3
Mr. Peter Fraser	Gladwall Engineering Services 6213 Wagner Road Edmonton, Alberta T6E 4N4
Mr. Gregg Gaylard	Western Sales Manager Urecon Insulation Ltd. P.O. Box 212 Calmar, Alberta T0C 0V0
Mr. Jim Gratz	Utilities Supervisor Town of Strathmore Box 1228, Strathmore, Alberta T0J 3H0
Mr. Ed. Harding, P.Eng.	Program Supervisor Water and Wastewater Program Westerra Institute of Technology Box 5000 Stony Plain, Alberta T0E 2G0

Mr. Andy Maguire	Rossdale Water Treatment Plant Edmonton Water & Sanitation 12220 - Stony Plain Road Edmonton, Alberta T5N 3Y4
Mr. J. D. McIntyre, P.Eng.	Municipal Utilities Division Alberta Utilities & Telecommunications 12323 - Stony Plain Road Edmonton, Alberta T5N 3Y9
Mr. Jim McKinley	Pesticide Chemicals Branch Pollution Control Division Alberta Environment 9820 - 106 Street, Edmonton, Alberta T5K 2J6
Mr. T. R. Roulston	Canadian Technical Pipe Rep. Manville Canada Inc. 9324 - 49 Street Edmonton, Alberta T6B 2L7
Mr. Dave Roulstone	Branch/Sales Manager Progressive Sealing Inc. 9753 - 54 Avenue Edmonton, Alberta T6E 5J4
Mr. G. B. Samuel, P.Eng.	Municipal Engineering Branch Pollution Control Division Alberta Environment 9820 - 106 Street, Edmonton, Alberta T5K 2J6
Mr. Dale Sawchuk and Mr. Roy Pyper	Sales Representatives Scepter Manufacturing Co. Ltd. 3611 - 9 Street S.E. Calgary, Alberta T2G 3C7
Mr. T. R. Schultz	Western Area Supervisor Municipal & Utility Division Rockwell International of Canada Ltd. 101, 7710 - 5th Street S.E. Calgary, Alberta T2H 2L9
Mr. Milton J. Tkaczyk	Rossdale Water Treatment Plant Edmonton Water and Sanitation 12220 Stony Plain Road Edmonton, Alberta T5N 3Y4
Mr. Stephen Tyler	Policy Analysis & Liaison Energy Conservation Branch Alberta Energy & Natural Resources 2nd Floor, Highfield Place 10010 - 106 Street Edmonton, Alberta T5J 3L8

Mr. Poul Wesch
BCA Industrial Controls Ltd.
13, 6113 - 4 Street, S.E.
Calgary, T2H 2H9

Mr. M. T. Yakemchuk, P.Eng.
Sales Manager, Pipe Division
Consolidated Concrete
Box 5150, Station E
Edmonton, Alberta T5T 4C1

Mr. Allan Yee, P.Eng.
Wastewater Treatment
Water and Sanitation
12220 - Stony Plain Road
Edmonton, Alberta T5N 3Y4

Mr. Herb Zinger
Utilities Superintendent
Town of Castor
Box 569
Castor, Alberta T0C 0X0

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WESTERRA INSTITUTE OF TECHNOLOGY
OPERATOR TRAINING PROGRAMS

Ed Harding, P. Eng. Program
Supervisor, Westerra Water &
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The objective of Westerra's Water and Wastewater Technician Outreach Program is to provide training for individuals who are presently working in the water and wastewater field or for individuals who are interested in the field and cannot attend the full-time program.

The program is available to students on an outreach basis through the use of correspondence course materials, audio-visual packages, telephone tutorials and some on-campus laboratory work.

A total of 12 instructional units are available in the Outreach Program.

GENERAL KNOWLEDGE	WATER DISTRIBUTION	WATER TREATMENT	WASTEWATER COLLECTION	WASTEWATER TREATMENT
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The next series of Outreach Courses will start on September 15, 1985, and on January 15, 1986.

THE STRAIGHT FACTS ABOUT THE PUMP INDUSTRY

Dave Roulstone
Rotating Equipment Specialist
Progressive Sealing Incorporated, Edmonton

Introduction

Regardless of what industry or applications where centrifugal pumps are found, we find that certain facts are common to all pumps and to all users of pumps.

This paper will describe maintenance related conditions concerning centrifugal pumps.

How Pumps are Specified and Purchased

Regardless of whether pumps are being purchased for a capital project (new plant or expansion) an extension to an existing system, or to replace an old, obsolete, or problem pump, an engineer decides what they need the pump to do as far as performance and materials required for the specific job, and a purchaser decides on where to buy it.

The engineer gives the purchaser a set of requirements concerning the hydraulics, i.e., he wants so much flow (GPM) from a certain height (total dynamic head) and he has a given suction (net positive suction available for his fluid). He may give added information regarding horsepower, speed, metallurgy, specific gravity, solids by volume, efficiency required and so on. The purchaser then sends it to a selected group of pump suppliers. The suppliers are usually chosen from an approved list based on past experience and good services. The customer may already have purchased many pumps from a particular company and is "locked in" because of spare parts inventory and what the customer considers as standardization. The usual course of events is that he must have two or three bids minimum, so the information is sent to many suppliers for quotation.

How the Pump Business Works

Now, it is up to the pump companies to decide which pump they wish to sell. It obviously must do the job specified by the customer and they can determine by pump curves which group of pumps will do the job, however, they may have several options as far as volute and impeller sizes, speed, metallurgy, frame sizes and horsepower are concerned.

It now becomes a matter of what the pump companies decide is best for them in order to:

- get the order,
- make sure of the most money possible as quickly as possible,
- ensure they keep the business for as long as possible.

1. To get the order means they must be the most competitive suppliers involved with the bid tender: almost in every case of a pump sale it is the lowest price that wins.

   If it is a large quantity of pumps being asked for, the pump companies will negotiate themselves a below cost loss just to get the order. Why? Because they want the spare tarts business from the end user; this is where they all make their money, not on the sale of the pumps.

2. After the pumps are on plant site, the end user will usually order some backup inventory such as a spare impeller and shaft or a volute and back plate and various other consumable parts.

   Only two of these parts may total more than the original price of the complete pump. These outrageous markups for spare pump parts are common to all pump companies, except one!

   This method of business demonstrates the politics and policies adapted over the past 80 years of not only the pump companies, who get their profits back in a hurry after winning a contract by bidding the lowest price, but also the customer who is working on a capital expenditure for a project which may be assisted by government grants and tax concessions. Any savings on major purchases of equipment means that money could be used elsewhere or considered profit margin to the department or contractor on the overall project price.

   The purchase of spare parts comes out of someone else's operating or maintenance budget and the engineer, contractor and purchaser have nothing to do with that.

3. How can the pump companies protect and ensure ongoing spare parts business? It is not difficult to hide interchangeable parts from one pump model to another by allotting different part numbers. The automobile industry tried this until the jobbers broke the code. Shouldn't the end user be able to ask for an interchange parts list for all the pumps he has from one supplier?

   If more than one pump is required and several different models would do the job, is it not more beneficial to the pump company to suggest different pumps or model variations than standardize the customer on all one type? Obviously this means more spares again.

   They can change part numbers and obsolete certain items so the end user must upgrade entire units to the new casting or component. All of these tactics lead to increased inventory levels and costs to the end user who wishes to avoid long lead times and expensive downtimes.

The pump companies over the years have clever managed to also avoid taking any responsibility for the majority of pump failures.

The Reasons for Pump Failure

90% of all pump shutdown occur for one or all the following reasons:

1) Stuffing box related problems and/or bearing related failure = 90%,
2) Corrosion, erosion and abrasion,
3) Operator or system related damage.

All of which the pump companies claim no responsibility for.

1. Packings and seals that fail and cause shaft or sleeve damage are the packing and seal suppliers' problem. The only responsibility the pump companies have is to supply the cheapest packing or seal because the customer wants the least expensive pump.

   Bearing failures are considered the responsibility of bearing manufacturers as are the oil/lip seals and the lubricant, their respective manufacturers.

2. If corrosion, erosion,or abrasion is the problem, then it is because of the product being pumped and the responsibility is on the engineer who specified the pump materials. If you want to fix this one, the pump company will tell you to upgrade the parts into special and exotic metals, at a real premium price.

3. If you have operations or system problems causing cavitation, damage, vortexing, recirculation, bent and broken shafts, piping problems etc., then you will have to live with it or fix it.

   Meanwhile, every day the maintenance departments in every industry suffer the enormous costs of keeping the rotating equipment running. The largest portion of process industries' maintenance budgets is allotted to rotation equipment.

Repair Costs

Each repair requires new parts and added costs.

Part examples: new sleeves or shafts, bearings, new packing or mechanical seals, oil and oil seals, o-rings and gaskets just for a minor overhaul.

A major overhaul may require the above plus a new impeller or a rebalancing, new wear rings and/or back plates along with casing repair or replacement. All of which adds up to a large expenditure in spare parts.

ITEMIZE YOUR TYPICAL COSTS FOR JUSTIFICATION OF CHANGE

Parts example: For cost analysis of equipment # ____________________

Item	Part Number	Number Required	Price (Each)	Total Repair $
Shaft Sleeve				
Shaft				
Bearings				
Packing Size		(lb/set)	/lb	
Packing Type		(#/rings)	/set	
Lantern Ring				
Mechanical Seal				
Gland, Pkg or seal				
Lip Seals				
O-Rings				
Gaskets				
Bushings				
Flingers				
Impeller				
Back Plate				
Casings				
Wear Rings				
Others				

Total: ____________________

Let us now consider the typical labour costs involved with removing the pump, repairing it and returning it after servicing.

If a customer is trade unionized, several different trades may be required to remove, repair and reconnect the equipment.

ASSOCIATED DOWNTIME / LABOUR COST PER PUMP REPAIR

Labour example: For cost analysis of man hours.

Trade	Number of Men	Total Man HOurs	Hourly Rate	Total
Pipe Fitters				
Electricians				
Millwrights				
Instrumentation				
Engineering				
Inspection				
Machinist				
Warehouse/Tool crib				
Others				

Total: ____________

Plus Parts Total: ____________

Now add in downtime, production loss costs ____________

Repair frequency per year (estimate or from records) ____________

This now gives us what the pump cost per wear is to maintain ____________

Add this to the quoted price of the original pump ____________

Grand Total ____________

The bottom line is: What does the lowest priced pump cost over one year, two years, three years or over the life expectancy of the pump?

These numbers now give us what the quoted "low cost pump" is actually going to cost over a period of time. It does not take into consideration such things as energy efficiency.

Energy Efficiency, Impeller Clearances, Seal Failures

Compared to other pumps and other sealing devices, balanced o-ring seals consume one sixth (1/6) of the electrical power of packing and could pay for themselves in one year over packing. Packing is like running your automobile with the emergency brake on. To obtain the best possible numbers, they use special impellers and special investment castings that are certainly not a regular line item. They will use a high quality balanced mechanical seal, special bearings, wear rings, oils and electric motors all "tricked up" to reduce friction and drag and pump very clean water at optimum temperatures and flow rates.

The number arrived at bears no resemblance to the actual low cost pump they quoted, or actual in plant performance. Note: Ask for actual test data parameters and procedures. The best way to establish an energy cost figure is to take an actual in-plant ampmeter reading off operating units and calculate the plant's energy cost multiplying out to the cost of a pump per year.

If you are looking for energy savings in pumps and electric motors, look for designs that have replaced lip seals with two-part non-contact, non-wearing permanent bearing isolators. (See chapter on Bearing Failures).

Oil/lip seals consume energy just like packing. Two conventional lip seals on a 3" shaft with SAE 30-200°F sump oil temperature turning 3600 rpm consume 0.75 of a hp or 0.75 kW x 0.06 kW/h x 24 hours/day x 365 days/year = 394.20 per year. Plus one more seal on the electric motor means over $500.00 for a pump per year. This could be saved by purchasing pumps and motors or retrofitting them with bearing isolators.

Pumps upgraded with high quality investment casted volutes and impellers and fitted with o-ring balanced mechanical seals also improve energy efficiency by as much as 20 percent. Another interesting fact about pump efficiency is how maintenance people set impeller clearances in different pumps. Some pumps require they be set from the suction side, others from the back plate. Some require specific calculations, adjustments, shimming, etc.

All of this gets done in the shop at overhaul time. Most companies will build in a corrosion factor in the casing that allows for approximately -125 thou. of wear. The pump impeller/shaft is adjustable to take up this wear or corrosion and still operate.

What few people understand is that for every 0.002" you miss the proper clearance setting, the pump looses 1% of pump capacity or efficiency. Miss it by 0.020" and the pump looses 10% capacity. Or put another way, on a 10 hp motor you loose 1 hp. 1 hp = 1 kW therefore 1 kW at 0.06 kW/h x 24 hours/day x 8,760 hours/year = $525.60/hp/year x how many pumps in the plant?

To be realistic, is it possible the clearance is correct in any, some or all of the pumps when they leave the repair shop? Your answer ____%. Estimate by how many thousands of an inch the average pump could be out _____. Using the formula, how much loss percentage is that? ____% and what is your power kW/h rate? Now consider that as a pump comes up to operating temperature, the shaft will grow.

Stainless steel grows at a rate of 98 x 10^{-6} ft./°F or 0.0000098. Carbon steel grows at a rate of 40% less.

Rule of thumb: For every inch of shaft it will grow 0.001 for every 100 degrees F. rise in temperature or, length x width and mark off 5 places.

For example: 10" long shaft x 2" diameter. Length x width = 20"
Temp. = 200°F
20 x 200 = 4000 mark off 5 places = 04000 or 0.040"
Actual calculation = 20 x 200 = 4000 x 9.8 - 0.039200

Now what happened to our impeller clearance? Go back to the formula and recalculate your estimate. Here is my example: What is your plant's estimated loss?

Fifty pumps with an average of 2" shafts X 10" long running approximately 200°F with 20 hp motors. All impellers and seals are being set in the main shop. Let us assume the millwrights get it right on 50%, and are 0.010 out on the other 50% so we have:

25 pumps at 0.010 = 5% energy loss.
5% of 20 hp = 1 hp x 25 pumps = 25 hp or $13,140.00 a year of loss energy.
50 pumps have all grown 0.040" or a 20% loss therefore 20% of a 20 hp = 4 hp x 50 pumps = 200 hp + 25 hp incorrect impellers = 225 hp loss x 24 hours x 365 days x 0.06 kw/h or as per previous formula:

1 hp = 1 kW = 525.60/hour/year x 225 hp = $118,260.00 worth of energy lost per year on 50 pumps.

Note: packaged pumps consume 5/6 more.

So we see by this example that in order to correct this situation all pumps should have impeller adjustments that are easy to do, as accurate as possible, and should be made after the pump has reached operating temperature. If your present design will allow you to accomplish these three critical procedures, what is wrong with this idea? The answer is the mechanical seal setting! Move the impeller and you disturb the seal.

The rotary unit of the seal is attached to the shaft at a specific point. The installation dimension is critical to the life expectancy of the seal. It varies from one seal manufacturer to another and indeed may be different for each type and size of some seals.

The major reason for seal failure is that the seal faces open up, allowing contamination, face damage and leakage. If the seal is not positioned perfectly with the manufacturer's specifications, i.e., undercompressed, this will lead to premature failure due to the springs not being able to compensate for face wear and back pressure allowing the faces to open.

Overcompensation will lead to rapid face wear from increased friction and heat which can affect the product and the elastomer, again resulting in premature seal failure.

Premature failure is defined as: leakage occurs before the carbon face is worn back to the holder or step. 85% of mechanical seals fail before they wear out. Check your seal faces: maintenance is changing parts not curing the problem. It now becomes clearer that seal installation procedures, impeller settings and thermal growth may well be the reason for a large percentage of seals that experience short life and pumps that are not running efficiently.

The solution is to use cartridge mounted o-ring balanced seals, preferably self-aligning and non-fretting. These features will guarantee you no further shaft or sleeve replacements due to shaft elastomer grooving. This grooving of the shaft is a result of seal movement causing oxide impregnation of the elastomer which becomes abrasive, cuts a groove, hangs up the seal, opens the faces and the seal fails.

Self-aligning (Chesterton patent #3,972,536 spring loaded stationary face) helps compensate for shaft movement caused by start up and bearing end play thrusts. Shaft deflection is often the result of a throttled discharge valve, cocking of the gland plate, misalignment, pipe strain and vibration. The self-aligning feature generally provides a more forgiving mechanical seal able to survive in mechanically poor systems and difficult sealing applications.

The cartridge design now provides almost error free installation; no measuring or positioning of the seal is required and it will now allow maintenance to adjust the impeller once the pump is up to temperature for maximum efficiency.

Bearing Failures on all Rotating Equipment

Books, manuals and papers have been written on this subject over the years. Most discuss the bearing manufacturing differences, installation procedures, lubrication and troubleshooting. All seem to admit bearing life on rotating equipment is not what it should be but little is offered as a permanent solution to the problem.

Hence the growing interest of "Vibration Analysis" for easier detection of bearing failures..

The facts:

1. Typically, bearings are selected and rated according to the "B-10" or L-10" projected life. It is defined as the life that may be expected by 90% of a given group of identical bearings operating under equal conditions of load and speed. The average (B-50) life of this same group of bearings would be five times the minimum (B-10) life projection.

   It is not uncommon to observe B-10 theoretical design projections of 300,000 hours (approximately 34 years) for common items of rotating equipment. It should be noted that the statistics listed above are from published bearing manufacturers' data and are pure theory.

   Practice: Observation of rolling element bearings that fail in field operation tells a completely different story: Theory and practical experience do not agree - and this is by a margin of 90%.

   In real life, bearings fail for a variety of reasons. Typically, these include:
   - Inadequate lubrication - 43%. Generally, this is a lack or excess of worn-out or contaminated lubrication.
   - Improper assembly - 27%. This includes improper fit, alignment on seating area, dust or abrasive particles deposited during or after assembly, etc.
   - Other - 21%. These various reasons such as excess temperature, shock loading, static brinelling, electrolysis and/or defects in manufacture.
   - "Normal" fatigue - 9%. What's so normal about 9%? Bearings that "die" of old age, i.e., fatigue, are rare indeed.

   Don't be alarmed at the 10% success ratio between theory and practice - it gives you a 90% opportunity for improvement.

   Almost 50% of bearing failures are caused by lack or excess of worn out or contaminated lubrication.

   Q. Could you estimate what that means in dollars to your company?

   A. $ __________.

2. Rotating equipment does not consume oil!

Q. Then why does every plant and industry employ people whose sole responsibility is to check oil levels, drain water out, and add oil to rotating equipment?

A. Because the oil seals don't work!

Q. If seals leak we are now allowing the human element to have an effect on the life of the equipment. If not enough or too much lubricant causes bearing failure is it logical to assume that in practice this is what is occurring?

A. ______________________________________.

3. One drop of water (0.002%) in a quart of oil will reduce the life of the bearing by 48%. 6% water contamination will reduce bearing life expectancy by 83% (mobil oil study).

The water displaces the oil film, ELASTROHYDRODYNAMIC FILM SEPARATION and caused metal to metal contact within the bearing, starting a chain reaction of wear and destruction.

Q. If packing and failed seals leak, can the leakage enter the bearing housing and contaminate the oil?

A. If you are adding oil, the oil seals are leaking. If oil can get out then contamination can get in.

Rotating equipment is often subject to conditions of dirt, dust, abrasives, hazardous chemicals and fumes. Leaking chemicals, spills and some food related applications require that the equipment and area is hosed down with water. All of which contribute to contamination related bearing failures.

4. Lip seal design life is extremely short compared to the bearings. C. R. - Chicago Rawhide is the leading manufacturer of oil/lip seals. They conducted a controlled test of their Double or Waveseal against a national, conventional oil seal (same as their own standard lip seal). The results were very interesting. The average of 10 of each type tested were:

	Conventional Seal	Double Lip Seal
50% failed after:	645 hours/27 days	1844 hours/77 days
93% failed after:	1366 hours/57 days	3000 hours/125 days (4 months)

The very best only give 3 to 4 months life in laboratory conditions versus 34 years of bearing design life. The frictional heat generated as the shaft spins inside the lip causes failure due to blistering, heat checking, hardening, lubricant breakdown and shaft scoring.

Maintenance departments have had little choice over the years but to accept these problems. Some designs have put rubber washers or flingers on the shaft to try and deflect leakage and contamination away from the bearings. This option does little more than produce a finer mist, which gets in behind the flinger and in the vent. Remember, it only takes a drop in a quart to give almost a 50% failure rate.

As we see by this example, the "cheap" lip seal used on the largest percentage of all rotating equipment, be it pumps, gear boxes, electric motors, pillow blocks or turbines, is the limiting item as far as equipment downtime due to bearing failure. The usual response from maintenance is; "We can't afford to tear the equipment down to replace a $5.00 lip seal.", so we suffer the consequences!

The answer would be a permanent, non-wearing device that would contain lubricant and exclude any possibility of contamination.

How to Upgrade and Protect Your Existing Equipment

Bearing Isolation

Since 1928, when synthetic rubber lip seals evolved from rawhide pitcher-pump leathers, these crude devices have been applied to automotive, agricultural and even industrial rotating equipment. They have a maximum design life, in normal operation, of approximately 3,000 hours - about four months to failure.

Energy intensive "oil-mist", delivered under a slight air pressure to individual bearings, has been extensively utilized in some instances when mechanical reliability was critical. Even though the aerosol mist is pressurized during delivery to the point of use, the pressure quickly dissipates when it escapes into the bearing housing. Contamination, again, is possible.

Recently, however, a unique non-contact, non-wearing permanent isolation device that has been proved effective has been developed. It is convenient for retrofitting existing rotating equipment and can be specified when selecting new processing machinery.

The non-contact metallic bearing isolator features labyrinth lube return paths, centrifugal and static contaminant expulsion capability and viton static seal members. The bearing isolator's purpose is to exclude all outside contaminants and retain the bearing lubricant. Because there is no contact with the bearing shaft or within itself, the bearing isolator will not wear out from use.

More than 40,000 bearing isolators are being used successfully in major chemical plants, paper mills, food processing plants, foundries, refineries and power plants. The bearing isolator is generally used to replace conventional elastomeric lip seals, which typically last less than 3,000 hours, while the bearings they protect can be - and are - selected to last 17 years or more.

As a testimonial to its effectiveness, the bearing isolator has gained acceptance in a number of important companies which have designated its use in written specifications for rotating equipment, i.e., Syncrude Canada. A 1,200 psi stream of water has been directed at the end bell of a motor. This severe test took off the paint without a drop of water penetrating the isolator.

Conclusions:

1. Isolators, used in conjunction with synthetic lubricants can help provide a profit centre for a company.

2. Design engineering, purchasing, project engineering and especially maintenance should be coordinated in a team effort to eliminate potential defects before they are introduced into a new facility.

3. Isolators and high performance synthetic lubricants should be used in stand-by equipment. In a short time, the entire plant will require less and less maintenance, thereby reducing cost and increasing productivity.

4. Isolators can be retrofitted to almost any rotating shaft and adapted to almost any bearing housing. Isolators can be fitted to pumps, electric motors, fans, blowers, steam turbines, gear boxes, pulverizers, pillow blocks, conveyers, rollers, centrifugals and machine tool spindles.

Implementation of high technology does work, hand-held calculators outperform slide rules. The isolator is just such an improvement over earlier approaches to preventing bearing wear. Further information for justification or assistance with specifications is available on request.

Corrosion, Erosion and Abrasion

Corrosion is caused by the pumped products pH reacting with the metallurgy of the wetted pump parts. With leaking packed pumps this can severely damage pump components not compatible with the product. Bases and floors also suffer. Check: Metallurgy - Someone may have specified a lower grade to be more cost effective.

Is the system acid washed or have new chemicals been introduced?

Erosion and abrasion is caused by the abrasives and velocity of the pumpage eating away the volute, impeller and wear rings. It usually requires expensive replacement parts: On older equipment, obsoleted parts complicate and escalate the cost of repair. These problems can now be solved by the use of Chesterton Metal Repair System.

This two part metal resin filled line of products is the latest technology available in the field for the repair of damage caused by impact, abrasion, erosion or corrosion.

We can rebuild worn areas, fill holes and cracks, provide abrasion resistant surfaces, and even repair underwater damage. The material will adhere to iron, steel, lead, aluminium, alloys stainless steel, brass, galvanized steel and even masonary, concrete and fiberglass.

Once cured it offers excellent compressive strength, impact and abrasion resistance, outstanding chemical resistance and cures to a hard, strong, well bonded substance that can be machined, drilled, tapped, sawed, sanded or otherwise finished to meet specific needs. Two abrasion resistant products are available for the toughest of applications.

With the Metal Repair Pump Program System, we can now repair volutes, impellers, wear ring seating areas, back plates, throttle bushings, shaft lip seal damage, keyways, bearing housings, cut waters, casings, stuffing boxes and glands. For a fraction of the cost of replacement of fabricated part we can now repair the damage and return the equipment to service in a matter of hours, saving maintenance dollars, downtime and increasing equipment life. For more information ask for M. R. S. Bulletin #72920.

Now let us address the largest reasons of pump failures, bearing related failures and/or stuffing box related failures.

Stuffing Box Failures With Packing

The reason for shutdown is usually centred around the fact that leakage can no longer be controlled. This is a result of shaft sleeve scoring, common to all conventional pump stuffing boxes. Repacking has become useless and the sleeve must be changed requiring complete disassembly.

This may prove to be the rare time that the lantern ring can be removed as usually they become jammed in and no longer line up properly with the connection. The packing rings behind them have become hard and over compressed and have not served a useful purpose for some time. The lantern ring instead of serving to provide cooling and lubrication for the packing is actually creating a worse problem because maintenance is left with little choice but to just keep changing the 2 or 3 rings next to the gland. These rings are now trying to do the work of 5 or 6 and the operator keeps on tightening down on them in order to compensate for excessive leakage. This situation becomes greater as the lantern ring moves away from the flush connection thereby causing more O.D. leakage.

More adjustments squeeze the packing lubricant out of the rings and overheat the packing causing glazing and burning on the ring I.D. Now we have a very abrasive, non-lubricating material running on the shaft that is incapable of functioning and leakage and scoring get worse and worse.

Corrective Measures

If possible, relocate lantern ring to the bottom of the box, drill and tap new connections.

The ring will do a better job of keeping out abrasives from the bottom of the throat bushing and enough flush fluid will still come back through the packing rings to help cool and lubricate the entire set. You will be able to change out all the rings.

All the rings will be more responsive to gland pressure. The first rings in can now be properly seated. This is critical to any packed stuffing box. Some pump designs prevent this relocation. In which case we can remove it entirely! However, I suggest you seek the assistance of an experienced and qualified Sealing Device Specialist who can analyze your specific applications. He can recommend the proper non-asbestos materials and will train your maintenance and operations people in the latest technological developments of Hydrodynamic Sealing Systems. Patented by A. W. Chesterton Co.

The proper application of these high technology, self lubricating counterflow packings will result in far lower leakage rates, less gland adjustments, lower friction and heat, far less shaft or sleeve scoring and energy savings from electric motor amperage reduction. More information is available on request.

If you wish to eliminate shaft/sleeve replacement as part of your pump maintenance along with eliminating the leakage entirely and save 83% of present packed pump energy costs, then you should convert your pumps, at the next opportunity, over to the Cartridge mounted, O-Ring Balanced, self aligning Mechanical Seals; many plants already have. Reference list is available on request.

Stuffing Box Failure with Mechanical Seals

The reasons for mechanical seal failure is such an involved subject that we address this subject with a separate paper. The best way to understand this subject fully is to attend the three day Rotating Equipment Sealing course we offer. Alternatively, one day or 4 hour in-plant sessions, complete with seal manuals are available on request.

As this paper is devoted to the every day maintenance problems associated with the Conventional Centrifugal Pump, let us analyze the relationship of present day pump stuffing box designs, with its effect on mechanical seal life.

All process pumps are designed for packings not mechanical seals. The Stuffing Box was designed in 1890 when rags were stuffed into the cavity to reduce leakage.

Refinery, petrochemical and indeed every industry in the world is taking advantage of the latest technologies available in order to operate more efficiently and competetively. When new plants are designed and built, they take advantage of the latest in computer monitored systems. Millions of dollars are spent in engineering and design work to ensure the "correct" specifications are written for the project. Engineering departments and highly experienced rotating equipment specialists spend hundreds of hours selecting and specifying sophisticated and expensive mechanical seals and support systems.

With all this money and technology, how can you assume that it would work well on a piece of equipment that hasn't changed its basic design in 90 years???

Remember 85% of all mechanical seals fail before they wear out! Is there usable face material left on your mechanical seals? Inspect them, If There Is, They Failed Prematurely .

Can a stuffing box designed for packing have anything to do with this atrocious world wide mechanical seal failure rate?

- The seals must be designed around the spaces the pump manufacturers determine.
- 3/8" cross section packing is most common on the A.N.S.I. size range of pumps.

A.N.S.I. stands for American National Standards Institution.

In 1955 an American Voluntary Standard was proposed to the major pump companies which attempted to standardize many areas of pump design in order to assist industry. It wasn't until 1971 that they got the pump companies' agreement to adopt some form of standardization. The standard was written for packed pumps, no provisions were made for mechanical sealed pumps. It merely stated that A.N.S.I. pumps would conform to certain "envelope dimensions" to allow interchangeability within all A.N.S.I. pump manufacturers. Which means, one manufacturer's pump could be changed out to another or a more competetively priced pump, without changing suction, discharge piping, baseplates, etc.

A.N.S.I. pumps are manufactured by: Goulds, Duriron, Worthington, A.W. Chesterton Co. Ltd. and others.

This would have been a good opportunity to rewrite the specs for pumps to accommodate the use of mechanical seals. However, over 14 years later, the original packed pump design is still the world wide standard.

Let us examine the short comings of the stuffing box for seals.

Small cross sections (3/8" is common) require that "skinny" mechanical seals must be designed to fit the radial space.

This makes the seals inherently weak. As temperature, speed and pressures increase, the seals suffer from overheating, imbalance, movement, distortion, hoop-stressing and rubbing. The pipeline industry is a perfect example of this problem. High pressure, high speed, often poor lubricating and dangerous fluids are required to be sealed. These conditions demand special criteria for seal design, which have to be compromised because of pump design. The result is extremely high downtimes and maintenance cost related to stuffing box seal failures.

The small cross sections or radial space also mean that only a small amount of liquid can fill the remaining voids after the seal is installed. This prevents adequate circulation of fluid. Friction created by the seal faces increases the product temperature and can lead to failure of the seal. Heat is the second biggest reason for all types of seal failure.

If the product pumped has solids or is abrasive, the inherent poor circulation leads to clogged seal springs or bellows, restricted seal movement (hysteresis) and failure. The solution to date has been to flush the seals with large amounts of cleaner liquid at higher than pump pressure. This of course requires extra equipment and costs and results in fluctuating process temperatures, process dilution, extra evaporation loads and increased energy costs.

Other alternatives employed are very expensive seals with special hard faces or double seals with auxiliary barrier fluid systems.

Access to the seals for cleaning, readjusting or inspection is impossible without complete disassembly of the pump. All because the stuffing box is designed for packing not seals.

Existing Pump Maintenance Summary

- Most pumps are purchased by lowest price competitive bid. After a sale, spare parts quickly escalate the original price of the pump.
- Pump designs have not changed in over 80 years with respect to the sealing areas.
- All pump stuffing boxes are designed for packing, not seals.
- 80 to 90% of all pump shutdowns are for bearing and/or stuffing boxes related failures.
- Only 10% of Rolling contact Bearings reach design life expectancy (approximately 34 years).
- 43% fail for lack or excess of worn out or contaminated lubricant due to lip seal failure.
- Lip seals maximum design life = 3,000 hours (4 months).

- One drop of water in a quart of oil will reduce life by 48%.
- Converting oil seals to bearing isolators will permanently protect the bearings and lubrication.
- Guaranteed to reduce annual rotating equipment costs by 20% annum.
- Converting from packings to Cartridge Mounted O-Ring Balanced, self aligning, non Freeting Seals will eliminate further shaft or sleeve wear, and leakage, and could save enough energy to pay for the conversion in 1 year.

Corrosion, erosion and abrasion damage can be restored by the Metal Repair System at a fraction of the cost and time of replacement of spare parts.

Conclusion

Present pump purchasing practice of buying the cheapest pump when added to the historical records of maintenance costs, spare parts pricing and inventory costs over the life of the pump are astronomical. Present day pump designs rely on failures (planned obsolescence) for repeat business.

Consultants, engineers, and pump companies refuse to change the status quo. By demanding the cheapest pumps they are standing in the way of technological improvements which would benefit the end users. (Return on investment).

The Solution/The Customer

The end user must be educated on what the latest technological improvements in the field of rotating equipment are.

He must be allowed to field test the components by retrofitting or replacing existing equipment. In order to carefully monitor the improvements compared to his historical maintenance records. Cost justifications can then be written for managerial approval for an R.O.I. Program (Return on investment). A set of accurate up-to-date specifications should then be written which will ensure that any equipment being purchased for any part of the customer's plant has to comply with the specification in order to be considered for any bid/tender, project, etc.

This practice will not destroy the competetiveness, desirable for major purchases such as pumps. However, it will ensure that a proper applies to applies comparison is being submitted and that the end user benefits by the technological improvements available to him for his new equipment.

It is the right of the customer, not the engineering firm to whom the project was awarded, to specify what equipment he must maintain after the plant or expansion is handed over to him. Example: When Shall Oil Company build a refinery the contractor builds it and purchases equipment according to the Shell specifications. Why should other industries do it differently? Engineering firms for the given industry and area should be contacted and invited to a one day seminar where they can be instructed on modern day techniques, procedures, technological improvements and the new specifications.

An example of pump specifications incorporating the latest in technology can now be met.

Bearing Specifications

For retro fit and original equipment

GENERAL: (Pumps, fans, turbines, gears, spindles, etc.)

Bearings shall be protected by permanent metallic, non-contact, non-wearing, radial-axial labyrinth pattern isolators as manufactured by Inpro/Seal, Inc., Rock Island, Illinois, A.W. Chesterton. The design shall permanently retain the lubricant in the bearing housing and prevent entry of foreign material into the bearing environment. Isolator components shall be made of non-sparking material. Lip-type seals shall not be used.

ELECTRIC MOTORS:

Totally enclosed electric motors shall be equipped with anti-friction bearings rated for 50,000 hour minimum L'-10 life expectancy and shall be fitted with Inpro/Seal bearing isolators so as to be suitable for "hosedown" and hostile ambient conditions. Contact-type shaft seals or flingers shall not be used.

Engineering Standard

25 HP thru 200 HP, 460V, 3 Phase

Squirrel Cage Induction Motors

BEARINGS:

1. Motors shall be fitted with anti-friction (ball or roller) bearings. Sleeve-type bearings shall not be permitted unless specifically designated in writing.

2. Both the shaft and fan end bearings shall have a minimum (L'-10) life expectancy rating of 50,000 hours. Bearings shall be of the open (not shielded or "sealed"), relubricatable design.

3. Motors rated between 25 HP and 200 HP inclusive shall have Inpro/Seal permanent bearing isolators installed on the shaft extension (and fan) end(s) to permanently prevent water and/or dust intrusion into the bearing area.

NOTE: Motors 20 HP and smaller, upon failure, shall be replaced with new motors of similar type, except with factory-installed Inpro/Seal bearing isolators or A.W. Chesterton bearing isolators.

Updated Pump Specifications

Pumps Specified for Mechanical Seals

Must have seal chambers which allow for 1" minimum radial clearance over the shaft or sleeve O.D. at the point where the mechanical seal is installed, therefore allowing maximum cooling, circulation and cleaning.

Seal chamber must have a removable sealed cover for access into the seal area without pump disassembly. It must be fitted with a pressure and temperature transducer for electronic monitoring of the seal environment.

It must have a minimum of 1-1/4" tapped hole in the side to provide tangential flushing to the seal.

Optional cooling jacket arrangement must be available. Face must be machined square to pump shaft and accommodate a gasket or O-Ring sealing face. Seal chamber must be interchangeable with a packing chamber .

Pumps Specified for Mechanical Packing

Packing chamber design to allow for the elimination of lantern rings yet allow for flushing. It must accommodate several sizes of packing. Provide even loading over all the packing, regardless of packing size used.

It must eliminate any wear on the pump or sleeve. Be designed to minimize leakage, reduce horsepower over standard packing, resist abrasive wear, and allow ease of repacking without pump disassembly.

A.N.S.I. Pump Design Specifications

- Open and enclosed impellers to be interchangeable for the same volute size.
- To incorporate an accurate method of axial impeller adjustment regardless of type of impeller for maximum efficiency.

- High efficiency impeller designs and castings with back pump out vanes for seal/packing chamber pressure reduction.

- A non-damaging locking device for impeller removal by one man.

Casing:

- To meet all A.N.S.I. specifications and AP1-610 Nozzle loadings.

- Centreline support to allow for even expansion when used in high temperature applications.

- Suction and discharge necks to be drilled and tapped with a minimum of 1/4 NPT. for pressure gages and piping connections.

- A vibration accelerometer fitted to the casing for monitoring of cavity, imbalance and impending bearing failure.

- Casing wall thickness to allow for 1/8" corrosion.

Shaft:

- must be solid 316SS or better and should meet or exceed a typical shaft deflection at an off design point (50%, 3550 RPM/inches) at the impeller of 0.004 maximum.

- there should be no sleeve attached to the shaft eliminating any secondary shaft seals.

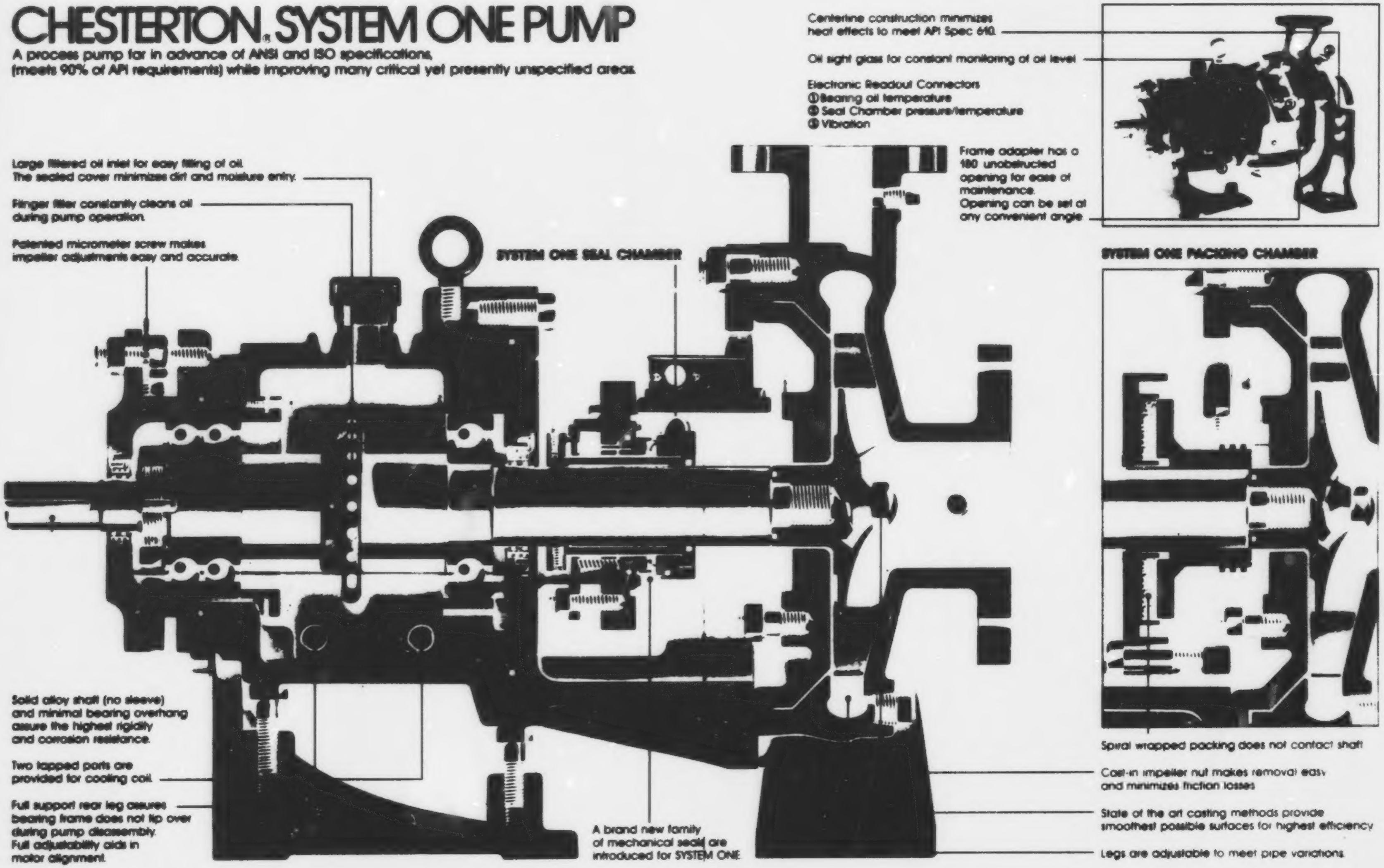
- Must be unconditionally warranted against wear damage at the packing or seal area as well as the bearing seal area for the life of the pump.
  (See enclosed System 1 Pump Warranties)

These are just a few examples of specifications which all industries can now take advantage of. The System 1 Pump can now meet all of these and many more specifications. These revolutionary and innovative ideas designed to reduce maintenance related costs on Centrifugal Pumps are being introduced to the world by the A.W. Chesterton Co., America's oldest packing manufacturer (100 years serving industry) who have earned a reputation world wide as the leading innovators of quality sealing devices and maintenance products. The recent introduction of the Chesterton Advanced System 1 Pump brings a new era of high quality, reliable, economic pumps to all industries interested in technological advancement to improve production, lower maintenance costs and increase efficiency.

For further details and assistance please contact the writer at (403) 437-1651.

CHESTERTON® SYSTEM ONE PUMP

A process pump far in advance of ANSI and ISO specifications, (meets 90% of API requirements) while improving many critical yet presently unspecified areas.



Centerline construction minimizes heat effects to meet API Spec 610.

Oil sight glass for constant monitoring of oil level.

Electronic Readout Connectors
① Bearing oil temperature
② Seal Chamber pressure/temperature
③ Vibration

Frame adapter has a 180 unobstructed opening for ease of maintenance. Opening can be set at any convenient angle.

Large filtered oil inlet for easy filling of oil. The sealed cover minimizes dirt and moisture entry.

Flinger filter constantly cleans oil during pump operation.

Patented micrometer screw makes impeller adjustments easy and accurate.

Solid alloy shaft (no sleeve) and minimal bearing overhang assure the highest rigidity and corrosion resistance.

Two tapped ports are provided for cooling coil.

Full support rear leg assures bearing frame does not tip over during pump disassembly. Full adjustability aids in motor alignment.

A brand new family of mechanical seals are introduced for SYSTEM ONE.

Spiral wrapped packing does not contact shaft.

Cast-in impeller nut makes removal easy and minimizes friction losses.

State of the art casting methods provide smoothest possible surfaces for highest efficiency.

Legs are adjustable to meet pipe variations.

Illustration of Chesterton System One Pump

EASE OF INSTALLATION - LIFE SUPPORT SYSTEM

Causes of Pump Failure	Ease of Maintenance support systems
Motor coupling Misalignment	- C. Flange Motor Adapter - Centerline design - Minimizes heat distortion
Pipe Flange Misalignment	- Volute is adjustable in 40° arcs - Slotted legs give three axis movement of pump - Jack bolts allow fine tuning of pump height - no shims - Centerline design - Minimizes thermal growth
Assembly/Disassembly	- Back pullout design - Power end is self standing - Axial jack bolts to remove power end - Center slot on rear leg allows pump to be worked on at site - Bolt heads conveniently located for maximum arc swing of wrench
Inaccessibility to Critical Areas	- 180° arc insures easy access to sealing area - Opening at seal area may be rotated

PACKING - LIFE SUPPORT SYSTEM ONE

Causes of Packing Failure	Packing life Support System
Improper Installation of Packing and Lantern Ring	- Designed out lantern ring - Repacking in less than 10 minutes
Heat	- 20 times more volume in chamber for better: lubrication, cooling, cleaning; prolongs packing life
Worn Shaft or Sleeve	- Packing does not contact shaft or shaft sleeve, therefore, no wear in these areas. - Eliminates many pump teardowns.
Uneven Packing Loading	- Packing is evenly loaded - Rotor and packing wears evenly because of spiral winding. - Spiral packing is squeezing radially toward center of gland. - Overtightening not a problem.

PACKING - LIFE SUPPORT SYSTEM ONE continued

Causes of Packing Failure	Packing life Support System
Solids Buildup	- Large passageways for ease in plushing away solids. - Spiral screw on rotor.

Pump teardowns are eliminated regardless of how or why the packing has failed.
Eliminates many pump teardowns.

MECHANICAL SEAL - LIFE SUPPORT SYSTEM ONE

Causes of Mechanical Seal Failures	Mechanical Seal Life Support Systems
Improper installation	- Seal chamber cover allows readjustment without pump disassembly - Eliminates pump teardown.
Heat	- 20 times more volume in chamber for better lubrication, cooling cleaning. - No heat checking, no thermal shock, no lifting of coated faces. - Prolongs mechanical seal life.
Restricted Movement From Clogging	- Seal chamber cover allows cleaning by steam or solvent without pump disassembly. - Eliminates pump teardown.
Seal Material Breakdown	- Very large seal cavity allows heavy duty cross sections. - Only top grade universal materials will be used, e.g., 316S/S, 548 RC Carbon 99.5 Al_2O_3 with hast. C springs. - Prolongs mechanical seal life.
Poor Environmental Controls	- Tangential flush inlet with 20X fluid content.
Improper Pump Operation	
(a) Vibration	- Solid shaft at seal
(b) Cavitation	- Oversized bearings
(c) Bearing failure	- Electronic readout

BALL BEARINGS - LIFE SUPPORT SYSTEM ONE

Causes of Bearing Failure	Bearing Life Support Systems
Heat	- Cooling fins; twice oil volume; cooling coil; C3 bearing clearances; no thermal window; no lip seal-heat; labyrinth oil seals run cool.
Contamination	- Labyrinth oil seals; filter flinger; magnetic plugs; filtered oil inlet; sight glass (oil condition).
Moisture	- Labyrinth oil seals (90 psig).; no breather in oil inlet funnel; breather is in labyrinth seal.
Wear	- Elimination of shaft wear at oil seals. - No oil lip seals to cause wear; labyrinth seal cannot wear shaft.

HYDRAULICS - LIFE SUPPORT SYSTEM

Causes of Pump Failure	Hydraulic Support Systems
Impeller Setting	- Built-in micrometer adjustment for both open and enclosed impellers.
Impeller Damage During Installation or Removal	- Cast-in Impeller bolt - Shaft Locking device
Corrosion Effects	- High alloy wet end. - Exchange enclosed for open impeller to eliminate casing corrosion effects
Cavitation/Recirculation	- High efficiency impeller design - design allows for operation over widest possible range. - Low NPSH requirements without forfeiting operation range.
Clogging	- Open impeller design has large passageways - Special impellers can be provided on certain size pumps (especially for paper mill applications)

PREDICTIVE MAINTENANCE - LIFE SUPPORT SYSTEM

A. Reactionary Maintenance

1. Teardowns are performed after massive equipment failure - extremely expensive method of maintenance.
2. Equipment failure determines time of shutdown, usually at an inopportune moment.
3. Usually an expensive repair job due to equipment damage.
4. Impossible to efficiently schedule other maintenance jobs.
5. Most important is the fact that it is dangerous to personnel working in the area.

B. Preventive Maintenance

1. Teardowns are performed at a predetermined period of time assuming that each piece of equipment has a fixed lifespan.
2. Recent international studies show this to be completely erroneous (i.e., United Airlines study):
   - (a) Only 8% of the equipment responds to planned maintenance.
   - (b) 11% of the equipment shows low failure frequency immediately following planned maintenance but quickly returns to premaintenance failure levels.
   - (c) 15% of the equipment has zero response to preventive maintenance.
   - (d) 66% of the equipment has an increase in failure frequency following preventive maintenance.
3. This means that:
   - (a) 92% of the equipment is seeing increased downtimes -- combination of planned and unplanned.
   - (b) Higher inventories required to cover increased overhauls.
   - (c) Productivity decreased, labor costs increased.
   - (d) Parts being discarded which still have some life left.
   - (e) Safety condition of the plant is still an unknown.

C. Predictive Maintenance

1. Using condition monitoring techniques, potential failures are predicted and a scheduled shutdown is planned.
2. This method solves many problems:
   - (a) Downtimes reduced to a minimum, only impending failures are shut down, productivity kept high.
   - (b) Labor force is kept to a minimum.
   - (c) No unnecessary parts replacements and reduced inventories.
   - (d) Condition of plant is constantly being monitored; therefore, safety is kept high and insurance premiums kept low.
   - (e) Avoids introduction of defects caused by time based overhauls.

System One Condition Monitoring Devices	Allows Failure Prediction On These Time Items
Oil sight glass	Bearing Oil
Removable seal chamber cover or plastic replacement	Mechanical seal wear rate and overall condition.
Electronics	
Oil temperature R/O	Stipulates when cooling is required
Seal chamber pressure/temperature, R/O	Condition of seal environment and its degradation
Vibration monitor	Overall condition of pump both mechanically and hydraulically including the following: Bearings Cavitation Impeller imbalance Bent shaft
Auxiliary Pressure Transducers	Can aid in determining a decrease in pump efficiency.

EXTERNAL CORROSION OF WATERWORKS HARDWARE

Karl Hartl, P. Eng.,
Manager of Business Development
Canron Inc., Toronto

INTRODUCTION

The role of a waterworks utility is to provide, first of all, protection of the health of the water consumer by producing and delivering to his home an excellent quality product and, secondly, to protect the safety of the public by having an adequate supply of water, under pressure, for fire control.

Unfortunately, most of the hardware in any water system is frequently exposed to corrosive environments. It becomes evident that the control of corrosion in waterworks systems can add greatly to dollar savings. It also increases public health protection by preventing contaminated liquid from entering drinking water systems and it increases the safety of the public by providing a more reliable fire control system.

The science of corrosion prevention and control has now progressed to the point of reliability. In waterworks practice, it is urgent that a high level of logic be applied to this subject. Not all environments are corrosive; not all materials corrode, and there is no single answer that applies to all corrosion problems that occur.

This paper is intended to provide design engineers, city officials, superintendents and operators with a basic knowledge of: the mechanism of corrosion; the types of corrosion cells that may be found in a waterworks system; and an evaluation of some environments with respect to potential corrosion. Present proven corrosion control and preventive measures will also be discussed.

Ductile Iron and Gray Cast Iron Pipe

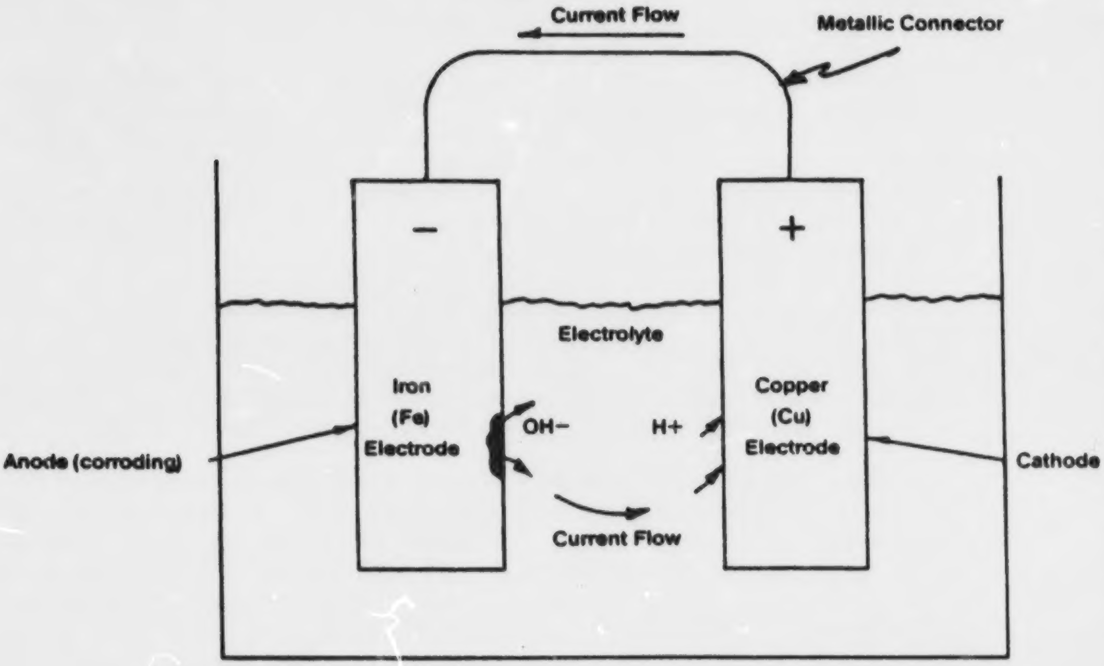
Since this paper deals with metallic hardware components, a few words have to be said at the outset about ductile and its predecessor gray cast iron pipe.

Gray cast iron pressure pipe has been in use for several centuries and thus provides us with a wealth of information on corrosion as well as experience in various methods of corrosion prevention and control. It has been estimated that over 500,000 miles of gray cast iron pipe are in services in North America in a wide range of sizes.

Ductile iron pipe is a relative newcomer, having been used extensively for water mains for the past two decades. Inasmuch as the metallurgical characteristics of ductile iron are somewhat related to gray iron, much of the technology developed for gray iron pipe can be applied to ductile iron pipe. However, there are two significant differences between these two products. First of all, ductile iron pipe is much stronger than gray iron and its structural strength is usually unaffected by corrosion pitting. Secondly, the graphite (carbon) structure in ductile iron takes the form of spheroids rather than the graphite flakes of gray iron, thus resulting in a somewhat different reaction to corrosive soil environments. Generally the passivating effect of corrosion products in ductile iron pipe is greater than that in gray iron pipe.

The Basic Corrosion Cell

Figure 1

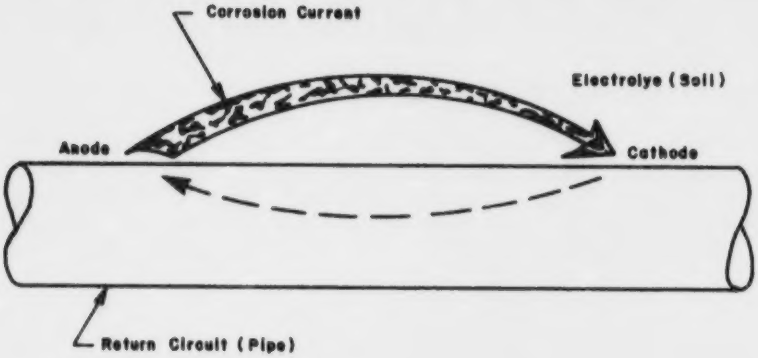


Inasmuch as metallic corrosion is an electrochemical process, four supporting components must exist for a corrosion cell to function: an anode (the metal or the area on a metal from which the electrical current leaves or flows); a cathode (the metal or the area on a metal to which the current flows); an electrolyte (the media through which the current passes); and a metallic connection between the anode and cathode (to complete the circuit). If any one of these components is absent or non-functional, the electrochemical process cannot proceed and corrosion cannot occur. Figure 1 represents the Basic corrosion cell. Thus, immediately, we are given several clues to corrosion prevention or control:

1. Removal of the metallic connection between the anode and cathode (insulation);

2. Isolation of the anode from the electrolyte (coatings and dielectric barriers);
3. Reversing the direction of current at the anode, thus making it a cathode (cathodic protection); and
4. Electrolyte control (analysis of the environment and installation of unprotected pipe only in non-corrosive soil).

Figure 2



Basic Cell Applied to a Pipeline

Figure 2 represents the basic galvanic corrosion cell as it may occur on underground pipe.

Note that all four supporting components exist as in the basic corrosion cell shown in Figure 1.

Corrosion Mechanisms

There are two basic mechanisms by which metals in electrolytes corrode. For the purpose of our discussion, these can be identified as:

1) Galvanic corrosion
2) Electrolytic corrosion

Galvanic Corrosion

Galvanic corrosion is a self-generated activity resulting from differences in potential which develop when the metal is placed in an electrolyte. These differences in potential can result from the coupling of dissimilar metals or they can result from variation in conditions which exist upon the surface of a single metal.

When two dissimilar metals are connected electrically and are immersed in an electrolyte, current will be generated and one of the metals will corrode. Current from the corroding metal will flow into the electrolyte, over to a non-corroding metal, and then back through the connection between the two metals. The corroding metal is the one where the current leaves to enter the electrolyte. Here are three examples of coupling of dissimilar metals regularly found in waterworks systems.

The worst culprits when dealing with differences existing upon the surface of a metal within an electrolyte are variances in soil resistivity, moisture and aeration along the pipe surface.

Electrolytic Corrosion

Electrolytic corrosion is a result of direct current from outside entering and then leaving a particular metal structure by way of the electrolyte. Where current enters the structure, that structure is unaffected or is provided with some degree of protection. Where the current leaves the structure, corrosion occurs.

In underground work, this type of corrosion is often referred to as stray current corrosion and is a result of currents entering the ground from sources of DC such as electric railways, industrial equipment such as welding and mine transportation equipment and existing cathodic protection systems.

Electrolytic and galvanic corrosion are similar in that corrosion always occurs at the anodes. The essential difference between the two is that in galvanic corrosion, it is the corrosion activity which generates the current whereas in electrolytic corrosion it is the external current which generates the corrosion. There is also a difference in polarity. In a galvanic cell the anode is the negative terminal and in an electrolytic cell the anode is the positive terminal.

The Search for Solutions

Corrosion was recognized as a threat to cast iron water and gas pipe early in the 20th century. In the 1920's the U.S. Bureau of Standards, in cooperation with the American Petroleum Institute, representatives of pipe and coating manufacturers and others, embarked upon extensive corrosion prevention research. As might have been expected, coatings available at that time helped deter corrosion in some soils but were inadequate in others. It was established that those early coatings on underground iron or steel pipe must often be supplemented by cathodic protection.

The Cast Iron Pipe Research Association continued the search independently and suggested trench improvements, coatings, cathodic protection, encasement in polyethylene film and alteration of bolt materials (for mechanical joints). Severely corrosive soil environments for these studies include organic swamp soils of New Jersey and the Everglades in Florida, low-resistivity alkali soils of Utah and California, man-made cinder beds and peat bogs of Wisconsin.

In the late 1950's and in the 1960's, concurrent studies were being conducted in operating water transmission and distribution systems where corrosion experience was recorded along with a number of soil characteristics.

Over the years, the knowledge of corrosive soil has improved immensely. For example, today we know that across Canada there are regions where corrosive soil is widespread as in Western Canada, whereas in Eastern Canada corrosive soil is localized to certain spotty areas.

Soil Evaluation

Based on hundreds of case histories over an extended period of years, it became possible to establish a specific soil evaluation procedure that would show whether soil corrosion would affect gray or ductile iron pipe. The 10-point system was presented formally to the American Water Works Association (AWWA) in 1968. It involves consideration of the factors listed herewith.

SOIL-TEST EVALUATION

Soil Characteristics	Points	Soil Characteristics	Points
Resistivity - ohm-cm (based on single probe at pipe depth or water-saturated Miller soil box):		Redox potential:	
		> +100 mV	0
		+50 to +100 mV	3.5
		0 to + 50 mV	4
< 700	10	Negative	5
700 to 1,000	8		
1,000 to 1,200	5	Sulfides:	
1,200 to 1,500	2	Positive	3.5
1,500 to 2,000	1	Trace	2
> 2,000	0	Negative	0
pH:		Moisture:	
0 to 2	5	Poor drainage,	
2 to 4	3	continuously wet	2
4 to 6.5	0	Fair drainage,	
6.5 to 7.5	0*	generally moist	1
7.5 to 8.5	0	Good drainage,	
> 8.5	3	generally dry	0

Ten points - corrosive to gray or ductile cast-iron pipe; protection is indicated.

* - If sulfides are present and low or negative Redox potential results are obtained, three points shall be given for this range.

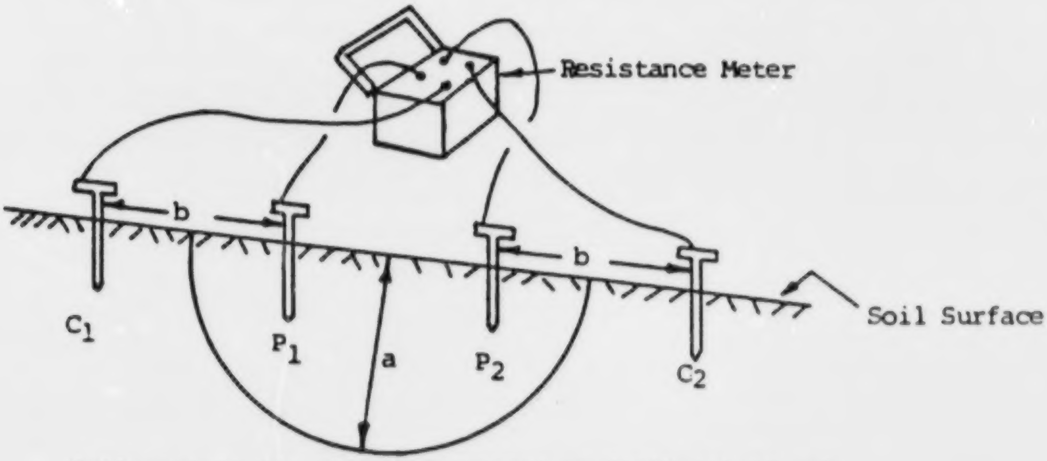
Using this system, points are assigned to the result of each test or observation. If the sum of points thus accumulated is 10 or more, the soil is corrosive to unprotected ductile iron pipe and protection is required.

This system was later incorporated into a specific AWWA guideline by adoption of AWWA Standard C-105 and Appendix A. The American Society for Testing and Materials (ASTM) adopted an identical Standard, A674, in 1974.

Let us take a few minutes at this time to study each of these items.

Soil Resistivity

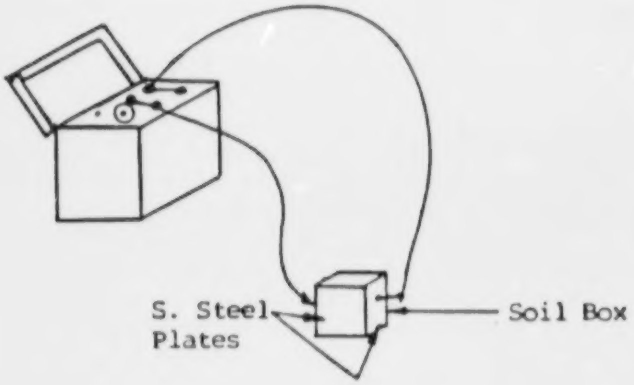
This test yields the reciprocal of conductivity; therefore, a low resistivity of soil means that it will serve well as an electrolyte. Resistivity is reported in Ohm-cm. Soil resistivity is the average result if the electrical resistance across each cubic centimetre of soil, in a given volume, could be measured. The test may be accomplished in several ways. For an average resistivity from near the ground surface to pipe depth or below, the 4-pin system is useful.



Soil resistivity will be averaged to depth (a) if a=b

The 4-pin system has serious limitations because it may average dry top soil with wetter subsoil, contaminated soil with clean soil, etc. Therefore, use of a single soil probe, is preferred for field tests. It is suitable for specific readings at various soil depths and enables the surveyor to search out the lowest resistivity soil that may come in contact with the pipe to be buried.

Inasmuch as the soil moisture may vary, it is advisable to remove a soil specimen from pipe depth for laboratory testing. The soil box or other such unit makes it possible to water-saturate the soil, putting available salts into solution and simulating the worst condition likely to occur after pipe installation.



pH

Soils with a pH below 4.0 generally serve well as an electrolyte, are high in total acids, and have a record of being aggressive.

Neutral pH (6.5 - 7.5) indicates that the soil will support sulfate reducing bacteria if other characteristics are suitable.

High pH soils (8.5 - 14.0) are generally high in dissolved salts and usually exhibit a low resistivity.

Oxidation Reduction Potential (Redox)

This test indicates the degree of aeration of the soil. Low or negative results show that the soil is anaerobic, this is, that there is no air or free oxygen present. Sulphate-reducing bacteria are able to live and grow in such conditions. A pH meter can be used for making the Redox test by using a platinum electrode in conjunction with the same reference electrode used for pH. The sample should be protected from exposure to the atmosphere until tested.

Sulphides

If sulphides are present in the soil, they indicate the likely presence of sulphate-reducing bacteria by inference. The sulphides test is qualitative and is accomplished by introducing a solution of 3% sodium azide in 0.1N iodine into a test tube containing a small quantity of soil removed from pipe depth. If sulphides are present, they catalyze a reaction between sodium azide and iodine with the release of nitrogen gas.

Moisture

Since the solid moisture may vary throughout the year, general drainage characteristics are recorded rather than specific moisture content.

As stated in the AWWA C-105 specification other factors may also give an indication whether or not the soil is corrosive. They are:

Soil Description:

In each investigation, soil types should be completely described. The description should include color and such physical characteristics as particle size, plasticity, friability, and uniformity. Observation and testing will reveal whether the soil is high in organic content. Experience has shown that in a given area, corrosivity may often be reflected in certain types and colors of soil. This is valuable information for future investigations or to determine which soils to suspect. Soils uniformity is important because of the possibility of development of local corrosion cells due to the difference in potential between unlike soil types, both of which are in contact with the pipe. The same is true for uniformity of aeration. If one segment of soil contains more oxygen than a neighboring segment, a corrosion cell can develop from the difference in potential. This is known as a differential aeration cell.

There are several basic types of soils which should be noted: sand, loam, silt, clay and muck. Unusual soils, such as peat or soils high in foreign material, should also be noted and described.

Stray Direct Current

Any soil survey should include consideration of possible stray direct current. The rapid increase in the use of rectifiers for cathodic protection of underground structures has resulted in a considerable threat from this source. Proximity of such cathodic protection systems should be noted.

Experience with Existing Installations

In addition to the above tests which will give clear indications of the ability of the soil to cause gray and ductile cast iron pipe corrosion, notes on prior experience in the area are extremely important and may, after all, be the best indication of soil corrosivity.

It should be mentioned at this point that corrosion engineers include chlorides in the evaluation of soil analysis. Since chlorides are salts and since these salts are a component measured in the soil resistivity item, the AWWA doesn't see the need to measure these salts specifically. As previously mentioned above, sulphides, however are a very important item that must be included in the AWWA test and the corrosion engineers neglect this item.

Canron is equipped to conduct soil tests as outlined in these Standards. The completion of such tests in ADVANCE of ductile iron pipe installation assures the owner that proper protective systems can be specified where needed.

Preventive Measures

Should the soil survey indicate the presence of corrosive areas, three alternatives are available to overcome this problem. They are:

i) Polyethylene Encasement

After years of study using adherent coating, trench improvement and cathodic protection, the system of wrapping with 8-mil (.008-in.) thick, loose polyethylene encasement was researched and resulted in the development of AWWA Standard C-105. This is not a coating although it offers the qualities of a coating, including high dielectric strength. It is mainly an environmental improvement. First, it reduces the environment to a very thin space between the pipe and the loose wrap, second it excludes direct exposure to corrosive soil. It does allow the entrance of ground water into the annular space between the pipe and wrap; however, the corrosive characteristics of the water are soon depleted by the action of initial corrosion, usually oxidation. Extensive use of this material has demonstrated its effectiveness for cast and ductile iron pipe in the following respects:

1. It provides a uniform environment for the pipe and thus eliminates local galvanic corrosion cells.
2. It offers good electrical shielding and thus resists the assimilation of stray direct current, presently and in the future.
3. Initial cost of material and installation are very low (less than 3% of pipe cost) and there are no maintenance costs.

The AWWA C-105 suggests three possible methods for installing this wrap, namely methods A to C as appearing in the specification mentioned above.

Polyethylene encasement is presently used throughout the world. Its success is evident from the general absence of corrosion failures where it has been properly installed. In Canada polyethylene encasement has not received widespread acceptance due to fears of damaging the encasement during installation. As with all other products, proper installation techniques must be followed to obtain the desired results. The failures that have occurred are a result of improper installation, such as the inclusion of corrosive soil inside the wrap, failure to repair the wrap when it is opened to effect tapping and grounding electrical currents onto the pipe, thus forcing corrosion at the point of ultimate discharge.

ii) Polymer Concrete Coating

Canron's 40 years of experience with Hyprescon (concrete pressure pipe) has demonstrated that the chemically basic hydrated cement (with a pH of about 11.5) has a passivating effect on embedded steel surfaces which greatly reduces the possibility of electrochemical corrosion. It is lime, contained in the cement, which passivates the steel when these two components become in contact with each other. With this in mind, means of protecting ductile iron pipe with concrete were sought, hoping to accomplish the same resistance to corrosion. The result of years of trial and error is a product that provides passivation at the iron-concrete interface. It is now available from Canron and is known as Hyprotec.

Studies by independent researchers namely the University of Toronto, W.H. Smith Associates of Illinois, U.S.A., and the B.C. Research Institute have established the following characteristics of this product:

The Water absorption rate as per the ASTM C-642, has been determined to be 4%. This is a significant figure since concrete which absorbs humidity permits corrosion to continue its path. By having such a low percentage of absorption rate, resistance to penetration by salts, sulphates and chlorides is provided.

The addition in the concrete of glass fibers increases the toughness of the coating resulting in an impact resistance as per ASTM G-14 of 40 ft-lb. The nominal thickness of this exterior coating is 4 mm or 0.16 inch.

This coating has high dielectric strength as its electrical resistivity has been established at 4.5×10^6 ohm cm which gives it a 92% efficiency against stray current.

Other important features of this product are:

1. It is maintenance free. No replacement parts are required and no periodic readings are necessary.

2. Because of its strength, Hyprotec pipe can be cut and directly tapped using procedures and equipment that are standard for ductile iron pipe.

3. The ends of the pipe are protected from corrosion by having a very liquid-like cement mortar poured in a diaper around every joint in a manner similar to the Hyprescon product.

4. Minor cracks in the exterior coating need no repair since the alkalinity of the concrete will provide an autogeneous self-healing corrosion barrier.

5. Polymer concrete coated iron fittings are available to obtain a uniform system.

When using Hyprotec products (as well as ductile iron pipe), unbonded joints should be specified to make this watermain into a modular system. Hyprotec pipe and fittings carry a 15% premium over regular material, but is well worth it.

The Polymer concrete coated ductile pipe has been used extensively across Canada since 1978. To date over a quarter of a million linear feet have been installed, without failure. Several municipalities accept only Hyprotec pipe and fittings in their systems.

iii) Cathodic Protection

The science of dielectric coating application, supplemented in the field by cathodic protection, has been thoroughly researched and is applicable to ductile iron pipe as it is to steel.

Cathodic protection is an electrical method of preventing corrosion. It is used on a wide variety of metallic structures which are in electrolytes such as soil or water. It operates by passing direct current continuously from electrodes which are installed in the electrolyte, to the structure to be protected. Corrosion is stopped when the current is of sufficient magnitude and is properly distributed.

Cathodic protection can be accomplished by sacrifical anode or by impressed current.

The Sacrificial Method

The sacrificial method of protection makes use of material, such as magnesium or zinc, to create a galvanic cell. The magnesium or zinc, as can be seen on the galvanic series, is less noble than or anodic to the component to be protected. Such anodes are self-energized and may be connected, for example, directly to the pipe. This type of system is usually used where it is desirable to apply small amounts of current at a number of locations.

The Impressed Current

The impressed current method uses anodes which are energized by an AC source rectified to DC current. In this type of cathodic protection system, anodes are installed in the electrolyte and are connected to the positive terminal of the DC source; the structure which is to be protected is connected to the negative terminal of that source. Because the power source is almost always a rectifier unit, this type of system is often referred to as a rectifier type system.

Our experience would indicate that water distribution piping is better suited to sacrificial anode cathodic protection than to impressed current systems. The obvious reason is that stray current damage to neighboring underground metallic structures such as gas lines, concentric neutrals on power cables and lead sheaths on telephone cables, is unlikely with sacrificial anodes but can be a problem with impressed current systems unless their application is extremely well coordinated with other utilities in the municipality. If cathodic protection of either type is to be used in a water system, we strongly recommend close cooperation with other utilities. Each locality should have a coordinating committee and the water utility should become involved so that any interference difficulties between cathodic protection systems can be avoided by proper advance planning.

The cathodic protection method can be utilized on new systems and also to prevent further deterioration to a watermain when an inadequately protected waterworks systems has been installed in corrosive soil.

Today there is a trend in the industry towards a modular cathodic protection system.

This system consists of dis-bonding each element from the next one and in providing a small but adequate sacrificial anode to each component of the waterworks system whether it be a pipe, a hydrant, fitting, copper service, valve, etc.

Currently iron pipe is the anode in a waterworks system. Iron pipe is being sacrificed to protect valves, copper tubing, hydrants, etc. It is this bad design practice that has given iron an undeserved reputation by sacrificing it to the benefit of other components in the waterworks system.

By using the modular system each element is protected from corrosion by its own individual sacrificial anode. The weights of the sacrificial anodes are based on the element to be protected.

The advantages of this system are the following:

- Long-line currents are eliminated
- Reliance of one material being protected by a less noble material in the same waterworks system is ended
- Danger of creating stray currents are avoided since very small sacrificial anodes are used.

Dis-Bonding the Pipe Joints

It had long been the practice in Canada to provide electrical bonding of ductile iron pipe joints. This facilitated the convenient electrical thawing of metallic service pipes in winter.

A potential corrosion problem may be created by joint bonding that otherwise might not exist. Long-line corrosion currents can develop on an electrically continuous pipeline due to variances in soil character. Also, stray current is cumulative and joint bonding makes the pipeline an attractive current path. If push-on joints are not electrically bonded, eight of every nine joints will retain sufficient resistance to discourage the accumulation of significant stray direct current.

The only reliable solution to this problem is to leave the rubber-gasketed joints unbonded, thus breaking the pipeline into small, electrically segmented units.

In addition to the potential corrosion problem associated with the electrical bonding of the joints, there also exists a safety problem. Past experience has shown that the use of the electrical thawing of service lines has occasionally set houses on fire. In the last two decades new methods have been developed permitting steam and hot water. These newer thawing techniques are recommended for both metallic and non-metallic pipe systems.

Insulating the Main from the Copper Service Connection

Bare pipes in direct connection with copper services can corrode, even without the influence of grounded currents. This bi-metal couple may result in a galvanic cell depending upon the resistivity of the soil and upon the mass or weight of the copper service. When we look at the Electromotive Series of Metals we notice that there is a large potential difference between iron and copper which explains the electromotive force which activates this galvanic cell.

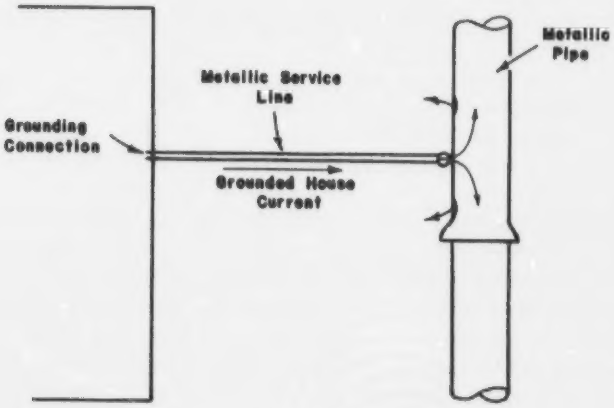
The solution to this potential problem is to provide effective insulation between the pipe and the copper service. Insulating bushings are available from nearly all corporation stop manufacturers.

Grounding of Electric Circuits on Water Pipe

The obligation of a water utility is to operate and to maintain its system at maximum efficiency, safety and economy from a waterworks viewpoint. It has no obligation whatsoever towards the electrical utilities.

The grounding of electrical currents onto the waterworks system can cause corrosion. In such an instance, the corrective procedure is to remove all such current from the service lines. Grounds rods have to be used for grounding electrical currents.

This next slide shows an example of the faulty system generally used in most water systems that have metallic piping systems.



Grounding of Electric Current on Water Pipe

Copper Pipe

Since copper pipe is more cathodic than ductile iron pipe, it is generally believed to be non-corrosive. Let us spend a few minutes to discuss the corrosion aspects of the product.

Although copper is normally resistant to underground corrosion, there are conditions which can cause this metal to be deteriorated by soil and certain direct burial hydrocarbon installations. For example, copper may corrode when the underground environment has 1) a high content of organic matter or high alkalinity in which the ratio of chloride and carbonate to sulfate is high; 2) high concentrations of organic and inorganic acids; 3) poor aeration which supports sulfate-reducing bacteria activity; and 4) a high chloride, sulfate, and/or ammonia content.

Corrosion of copper by a soil can be aggravated by the application of fertilizer and heavy lawn sprinkling, especially if the soil is poorly drained. Copper should not be embedded directly in cinders or in tidal marshes where it may be subjected to attack by sulfur compounds.

Underground copper water pipes can also be subjected to deterioration by stray direct current (DC) flowing in the soil. Generally when this occurs, the source of the stray DC is a nearby impressed-current type, cathodic protection system such as might be used to mitigate corrosion on steel gas mains and service lines which are exposed to corrosive soils.

Another hazard to underground copper is the electrical grounding practice. Alternating current (AC) systems are often grounded to the underground water systems. If copper tubes are connected to non-conducting (e.g. cement-asbestos and plastic) mains, corrosion damage can occur where the current leaves the copper, even if the current is alternating. Alternating current reportedly can be rectified by copper oxide films on the exterior surface, as it apparently becomes semi-conducting under certain soil, pH and electrical field intensity conditions leading to the underground corrosion of copper.

Copper exposed to an aggressive environment should be isolated from it with an inert moisture barrier, a wrapping of insulating tape, a coating of an asphaltum paint or with some other approved material.

Piping Appurtenances

So far, we have dealt with pipes in general, let us now deal with pipe appurtenances.

Valves, fittings, hydrant, repair sleeves, tapping saddles and other piping appurtenances often involve more than one metal. This may create bi-metal galvanic corrosion cells that are important, depending on the ability of the soil or water to serve as an electrolyte. It is necessary that metals of different nobility be insulated from one another or that these units be redesigned to avoid bi-metal couples. As a general guideline, any two metals that lie far apart in the electromotive series constitute two of the necessary components of a corrosion cell -- the anode and cathode.

In the past, the bolted mechanical joint used on pipe and fittings sometimes suffered corrosion of a slightly different nature due to the great difference in mass between the pipe and bolts. Extensive studies over a period of many years revealed that the sacrifice of bolt material could be stopped by slightly increasing the nobility of the bolt metal. This was accomplished by alloying the iron steel with copper, nickel and chromium. This alloy bolt is described in AWWA Standard C-111 and calls for 0.25% nickel, 0.20% copper and a combined nickel, copper and chromium content of 1.25%. Results of the use of these bolts have been most satisfactory, both in research test sites and on operational water system exposures.

Summary

Economical corrosion prevention methods are available and Canron stands ready to help in soil evaluation and problem analysis where ductile iron pipe is involved, or in establishing a corrosion control program for your water piping system.

We recommend the following program for water utilities who are concerned about corrosion.

1. Complete selected soil tests in advance of ductile iron pipe installation to determine whether any corrosive areas are present. Use the criteria presented in appendix A of the AWWA Standard C-105.

2. If any soil along the route of the pipe is determined to be corrosive specify one of the three preventive measures outlined earlier.

3. Do not electrically bond the pipe joints.

4. Provide insulation between copper services and ductile iron pipe.

5. Adopt the AWWA recommendation regarding the grounding of electrical services to the waterworks system.

6. Avoid bi-metal couples where possible in underground waterworks equipment, especially in soils with low resistivity.

7. If cathodic protection is used for water distribution piping, electrically isolate each component of the waterworks system and provide sacrificial anodes to each of these components.

8. In order to avoid putting additional stray current into the ground, consider the sacrificial method safer than the impressed current method.

As a closing remark, I would like to point out that the AWWA corrosion control committee which is composed of consulting engineers, corrosion engineers, water utility representatives and material producers have prepared a corrosion manual pertaining to public water supplies. This manual has been in preparation for over four years and the final version of this documents stands an excellent chance of being approved and printed early during 1985.

I strongly recommend the reading of this manual when it becomes available.

Canron has devoted and will continue to devote time and effort into research and development to find solutions to corrosion of iron pipe. Canron believes that even for corrosive environments, a protected iron pipe will give longer trouble free service than other products.

THE CARE AND MAINTENANCE OF THE LABORATORY EQUIPMENT USED IN A WATER OR WASTEWATER LABORATORY

Neil Sutherland
Fisher Scientific Ltd., Edmonton

The talk is intended to provide some hints to the users of the typical laboratory equipment found in a water or wastewater laboratory, to ensure accurate results and to maximize the equipment's life. Electronic maintenance will not be covered.

Balances

Balances generally fall into two categories: - The Analytical Balance with a readability of 0.1 mg and the Top-Loading or Triple-Beam Balance with a readability of 0.1 or 0.01 grams. Care and maintenance of the 0.1 mg balance, obviously, is more critical. On both types the newer electronic balances utilizing a load-cell, as opposed to a beam and weights, require much less maintenance than the older style. Also vibration effects, etc., are much reduced as these balances actually take 1000 readings in 1.6 secs and the displayed result is the average of these 1000 readings.

The laboratory should have a method of verifying the accuracy and the linearity of the balances and adjusting the newer types, if necessary. The best way is to have on hand a weight set with a tolerance equal to the tolerance of the balance. This generally means Class S in the case of the Analytical Balance. One weight can be used, but obviously the accuracy can only be checked at the value of the weight. Linearity can be checked by making a series of rough tare weights from any convenient material and conducting a series of weighings by checking the one calibration weight after each addition of a tare weight. The accurate weight should read the same all the way up scale ± the tolerance of the balance. "Corner-loading" should also be checked by noting the weight of an object when placed in the centre of the weighing pan and then four readings with the same object at the edge of the pan. If the readings differ by more than ± 2 least significant digits, the suspension system is not moving perpendicularly and must be adjusted by a qualified serviceman.

On the older beam balances incorporating a beam, knife-edges and weights, in addition to the above checks, periodic cleaning is also necessary. This is best accomplished by utilizing an aerosol can of compressed air. Care should be taken to avoid handling the beam or the weights with bare hands. Nylon gloves should be used.

pH

Over the years, the pH meter has developed into a very reliable instrument and there is virtually no maintenance necessary nor possible. 99% of any pH problems lie with the electrode(s).

Some meters have a "test" position to check the operation of the meter by bypassing the electrode input. If your meter doesn't have this function, the meter can be checked with the shorting strap connected between the two electrode jacks. When the shorting strap is in place, smooth meter deflection should track the calibration adjust knob. If a jumpy or totally erratic display results, there is a fault in the meter.

The measurement electrode, today, is a Silver/Silver Chloride electrode which has one very important property - it does not have a temperature co-efficient at pH 7.00. To verify this, immerse the electrode in pH 7.00 buffer and calibrate in the normal way. Now adjust the temperature dial and you should observe no display change. Now go to pH 10.00 (or 4.00) buffer and you will notice a significant change. This demonstrates the need to read and adjust the meter for temperatures. The farther the reading is away from 7.00 the more important this setting becomes. An automatic temperature probe would do this automatically.

If your meter has a slope control this setting is used to adjust the readings when the electrode does not respond perfectly to the Nernst equation. You set calibrate with pH 7.00 buffer, observe the reading in pH 10.00 or 4.00 buffer and adjust with the slope control if not right on. If you do not have a slope control, you can accomplish this with the temeperature dial. However, if in making the slope adjust, you find that the temperature pointer is now not at the temperature of the buffer, you will have to carefully remove the temperature knob from the shaft and reset to the correct temperature. This is only necessary for changing an electrode.

The most important point in regard to electrodes is their care and maintenance. The glass or measuring electrode is fragile. The fragile element is the spherical bulb at the tip. Care should be taken to adjust the stop on the electrode support rod to prevent contact with the bottom of the sample vessel. The internal filling solution (inaccessible) is 0.1M Hydrochloric Acid and like all membranes the glass membrane will remain viable if conditioned with a like material on either side. This means that it is best to store this electrode in weak hydrochloric acid or a prepared Electrode Conditioning Fluid. This is very important in putting a new electrode into operation where a 12 hour soak is recommended. Some provision should be made to prevent evaporation from the soaking vessel.

Fisher lists both a conditioning fluid and an O-ring capped storage bottle.

The reference electrode or the outer body of a combination electrode also requires maintenance. The liquid junction, today, is generally a small ceramic plug which ensures an even flow of the filling solution into the sample and establishes electrolytic contact. However, if the plug becomes non-wettable, no flow results. This can generally be cured by running hot water over the electrode tip. The correct filling solutions for reference electrodes are saturated potassium chloride if you have a single electrode and 4M potassium chloride taken to saturation with silver chloride, if you have a combination electrode. In both cases, a few crystals should be visible in the electrode. If a crystal build-up is visible, there is a danger that no flow can result. The electrodes can be flushed with distilled water and refilled.

For those of you in a water laboratory performing fluoride analysis using the fluoride electrode, this electrode should not be stored wet as the crystal detector is slightly soluble in distilled water and a shortening of its life will result.

D.O.

Like pH most of the maintenance on the D.O. meter lies with the probe. The meter itself, outside of replacing batteries, does not require maintenance.

The electrode does require periodic refilling and membrane replacement. The filling solution, this time, is 50% saturated potassium chloride. Care should be taken to avoid bubbles under the membrane. Small (less than 1 mm) bubbles are not important but large ones are. A smudge-like deposit forms on the gold electrode surface after several hundred hours of use. This should be removed with a paper-towel. If it proves quite stubborn a mild abrasive can be used.

When calibrating the meter using either the air or saturated water method, the barometric pressure connection is important. If you do not have a barometer and phone D.O.T. or an airport for the reading, it is important to obtain the uncorrected value (i.e. not sea-level).

Turbidity

Again, a reliable instrument that requires little maintenance other than changing the source lamp. Some tips are important, however. The sample vials should be examined before use to ensure that there are no scratches on their surface. A simple test of rotating the vial and observing the readings will show scratches by non-reproducible readings. Periodic checks should be made with a Formazin standard to verify the linearity of the instrument.

The Still

Here periodic maintenance is a must. The problem is scale build-up in the boiler chamber which if not removed will cause foaming and if the boiler foams into the condenser, obviously, the result is that the product water is not of distilled quality. For the water lab which has a conductivity meter a periodic check of the product water will be a good monitor. Metal stills in perfect condition will normally produce water in the 1 megohm range with glass stills a bit higher. Cleaning with acid is about the only way to effectively remove the scale. On the metal still this means removing the condenser at the flange joint between the boiler chamber and the condenser (order a new gasket before you do this). On the glass stills it generally means simply adding the acid to the constant level device and turning the still back on. Obviously the product tube should be directed to waste while cleaning is being performed.

Titration Assemblies

Since most labs do not have automatic titrators, therefore the comments here are for manual assemblies.

The burettes themselves require periodic cleaning with a good detergent to prevent scum build-up. Inaccurate results can be caused by "tailing" or "hang-up" of the titrant in a dirty burette. A properly-sized burette brush is necessary.

An assembly with three-way stopcock, auto-zero burettes is recommended so that the titrant is fed by gravity from a titrant storage bottle on a wall-shelf. Drying tubes filled with a mixture of Tel-Tale Silica Gel and Ascarite should be used on the top of the titrant bottle and the top of the burette to isolate the titrant from the moisture and the carbon-dioxide in the atmosphere. Any photosensitive titrants such as silver nitrate should have a light-occluding bottle or more simply an aluminum foil sheath. Titrant strengths should be chosen to simplify the calculations, e.g., N/50 Sulphuric Acid when used as the titrant for alkalinity will result in the burette readings being exactly 1/10 of the alkalinity in mg/calcium carbonate with a 100 mL sample, 0.0282N Silver Nitrate results in 1 mL of titrant equals 1 mg of chloride, etc. When pipetting samples, observe the code letters on the mouthpiece end of the pipette. T.D. means "to deliver" and this means to deliver by gravity and so these pipettes are not intended to be blown out. T.C. means "to contain" and are intended for the last drop to be blown out.

In general in regard to the maintenance of the laboratory equipment, it is recommended that a small log-book or a card file be maintained and that each entry is dated and initialled.

FLOW METERS FOR MUNICIPAL APPLICATIONS

P. Wesch, BCA
Industrial Controls Ltd., Calgary

Introduction

This paper is intended as a review of the limitations of the major primary liquid flow meters used in the water and wastewater production, treatment and transmission processes. Improvements in old technologies are constantly being made and new technological developments add new primary elements yearly. It is anticipated that the information contained herein, will, of necessity, require revision within a year or two.

The most misunderstood terms relating to liquid flow measurement are accuracy and rangeability. The term "% of rate" is best illustrated by an example. If the accuracy is stated as ±1.0% of rate, a corresponding range must be stated. Let us say the range is stated as 10:1. In the case where the maximum scale is 100 GPM, then the range is from 10 to 100 GPM and anywhere in this range, the accuracy is ±1.0% of the instantaneous flow rate. At 100 GPM, then the meter would be within ±1.0 GPM. At 10 GPM, the meter would be within ±0.1 GPM. Conversely, if the accuracy is stated at ±1.0% of full scale, the accuracy at 100 GPM would be ±1.0 GPM. However, at 10 GPM, the error would still be 1.0 GPM. This is a 10% error based on the instantaneous rate of 10 GPM.

Most primary liquid flow sensors measure velocity, and in effect, multiply the velocity times the sensor's cross-sectional area to produce a signal linear to flow rate. All such sensors should be calibrated in a flow test laboratory at the number of points empirically determined to assure meter accuracy throughout the range. The flow laboratory accuracy should be traceable to the U.S. National Bureau of Standards (NBS), or equivalent, so the flow tests can be relied upon. The NBS recognizes only turbine flow meters (due to their excellent repeatability) as a secondary standard.

In order for a manufacturer to assign a specific accuracy to a flow meter, the Scientific Apparatus Maker's Association (SAMA) requires that the meter be tested in a laboratory which is ideally accurate to 1/10 of the flow meter accuracy rating. 2/10 is acceptable. The outside limit is 3/10.

Limitations of turbine, vortex shedding, target, thermal, pitot, pitot mag, probe type mag, and positive displacement meters are not included as they are rarely applicable (or used) in the water and wastewater production, treatment and transmission processes.

I Venturi and Other Differential Producing Flow Meters; meters based on Bernoulli's Theorum.

1. Accuracy and Rangeability - The accuracy of the primary device is good over a reasonable range. However, it is an inferential device producing a differential pressure and does not measure velocity directly. The square root of the differential pressure must be extracted as the differential pressure is proportional to the square of the flow rate.

   Secondary devices used to interpret the differential pressure as velocity cause accuracy degradation limiting the rangeability. Realistically, a 1/4% of scale differential device is the best in common use.

   To be within ±1.0% of rate over a 10:1 flow range, the square root of the sum of the squares of the differential pressure measurement error and the square root extraction error cannot exceed ±0.01% of full scale. A 0.1% differential pressure measurement error at 10% of flow produces in excess of 10% or rate error. The best range that can be achieved with a ±1.0% of rate accuracy stipulation is about 4:1.

   Some manufacturers claim their newer units have a 5:1 or 6:1 rangeability at ±1.0% of rate.

2. Repeatability - Usually rated at 0.1% or 0.2% of scale permitting use where repeatability is the primary application design criteria.

3. Flow Profile Limitations - These devices are very sensitive to flow profile as anything which changes the upstream velocity distribution or downstream vena contracta causes significant errors. Normally 10 diameters upstream and from 2 to 3 diameters downstream is adequate. Accuracy is adversely affected by jets and/or swirling flow so these conditions should be avoided.

4. Liquid Limitations - In orifice plates, a very small amount of rounding of the throat entrance due to wear by abrasion or pipe wall coatings causes significant errors. The same is true of the venturi meter. Partial or total plugging of pressure taps creates substantial errors and maintenance problems. In the past several years, pressure opposed diaphragms at the pressure taps have been utilized to minimize this problem but this introduces additional initial installation and maintenance costs and difficult to detect errors after initial field calibration.

5. Normal Applications - The venturi meter together with orifice plates are widely used liquid flow measurement devices. This is in part because of their simplicity and

reliability and partly because Bernoulli's Theorum was the first widely used and understood primary (liquid and gas) flow measuring technology. Later technologies, which will be presented next, are rapidly replacing the differential producing primary sensors in more difficult liquids and in cases where good accuracy over a wide range is required. This is especially true as meters based on newer technologies become more mature and their costs are reduced. Venturi (and orifice) meters are often used in the water and wastewater industries in the following applications:

(1) Raw Water
- Wells*
- Lakes
- Rivers
- Ponds
- Springs

(2) Water Treatment Plants
- Influent
- Filter Effluent**
- Backwash Water
- Plant Effluent*
- Filter Spray Wash*
- Chemical Make-up Water*

(3) Wastewater Treatment Plants
- Treated Effluent*
- Plant Water*
- Tertiary Treatment Flows (not including sludges)

* To a large part replaced by other types of meters.

** Based on repeatable rate requirements and not on accuracy. Approach condition requirements for accurate flow measurement are usually violated.

6. Entrance Head - Requires a sufficient inlet pressure to produce the flow through the restriction of the throat. The entrance head is much higher than the head loss as much of the differential is recovered in the tapered recover section.

7. Full Pipe - The flow meter must be installed in a pipe which flows full.

II Propeller Meters

Refer to AWWA Specification C-704-75.

1. Accuracy and Rangeability - The AWWA specification requires an accuracy of ±2.0%of rate over a specified range. The range is about 10:1 except for sizes less than 6". Based on thousands of flow tests, Sparling has determined that the meter must be tested at a minimum flow rate, at a mid-point flow rate and at as high a flow rate as can be produced up to the maximum in order to assure accuracy at all points in the flow range.

Propeller meter minimum flow ranges are limited by the starting friction of the mechanism. Maximum flow ranges are limited to such rotational speeds that permit long life, usually five (5) years average time between repair of working parts in contact with the liquid for meters from 2" to 24". Longer working part life can be expected from 30" and larger meters. Most propeller meters may be over-ranged to 150% of the rated maximum flow rate for 10% of the operating time (2.4 hours/day) without voiding the manufacturer's warranty. Most manufacturers have designs with low and high ranges for each size using propellers with different pitch angles and/or different bearing materials or both.

2. Repeatability - 0.25% of rate can normally be expected.

3. Flow Profile Limitations - Propeller meters are good flow profile averagers due to the large percentage of the cross-sectional area of the conduit intercepted by the propeller. Jets which cause a disproportionate amount of the liquid to pass around the propeller will cause low readings. Jets causing a disproportionate amount of the liquid to pass through the center of the blades cause high readings. Spiraling flows cause either high or low readings depending on whether the spiral is turning in the same direction as the propeller (high readings) or in the opposite direction (low readings).

   A standard turbulent flow velocity profile is required at the propeller to meet the standards of ±2.0% of rate accuracy and 10:1 flow range requirement. Normally, 5 diameters of meter size straight pipe preceding the meter and one diameter downstream are adequate to meet this requirement. If bi-directional measurement is to be made, approaches for the reverse flow direction must equal the forward flow approach conditions. As propeller meters are good averagers, degradation of accuracy by shorter approach conditions is not as great as for some other types of primary flow devices.

4. Liquid Limitations - Propeller meters are operable in a variety of liquids other than those which are water based. The meter may be tested in water unless the viscosity of the liquid is very much different than the viscosity of water. Rangeability is limited by temperature effects on viscosity.

   Propeller meters are essentially clean water meters. Propellers and their supports are fouled by collection of debris carried by liquids. Stringy materials, especially in grease bearing liquids, effectively induce drag sufficient enough to lower the meter accuracy and eventually to stop the propeller rotation altogether

(1) Raw Water
- Wells
- Lakes
- Rivers
- Ponds
- Springs

(2) Water Treatment Plants
- Plant Influent
- Filter Effluent
- Backwash Water
- Plant Effluent
- Plant Water
- Filter Spray Wash
- Chemical Make-up Water

(3) Wastewater Treatment Plants
- Secondary Settling Tank Supernatant
- Treatment Effluent
- Plant Water
- All tertiary flows (including unprocessed sludges and filter backwash, but not including digested or thickened sludges).

6. Full Pipe - The meter must be installed in a pipe flowing full.

7. Head Loss - Very low, measured in inches of water.

III Transmissive Ultrasonic Flow Meters; (Difference Frequency Technology

1. Accuracy - The usual accuracy statement is ±1.0% of rate from one ft/sec to a maximum velocity. From zero to 1.0 ft.sec, the accuracy is usually stated as 0.015 ft/sec. To determine the percent of rate error at a specific flow rate in a given pipe size, divide 0.015 ft/sec by the flow rate in ft/sec and multiply by 100. Example: The error at 0.5 ft/sec is 0.015 ft/sec divided by 0.50 ft/sec = ±3.0% of rate.

   The sensor should be tested at zero flow rate, one ft/sec and at three higher flow rates. Zero flow rate error in ft/sec is especially critical as it represents the base error of the meter.

2. Rangeability - The maximum flow rate is fixed not by the technology limitations but rather by the individual manufacturer's design and perception of the maximum required by applications in the industry served. The design maximums vary but are never less than 25 ft/sec and can be as high as 100 ft/sec. The maximum end of the range is determined by the percent accuracy desired (usually ±1.0% of rates) which is readily achievable in 4" and larger sizes.

3. Repeatability - ±0.3% above one ft/sec.

4. Flow Profile Limitations - Transmissive ultrasonic meters transmit ultrasound pressure pulses alternately upstream and downstream at an angle to the flow through the centerline of the pipe. Flow profile conditions in which a disproportionate amount of the liquid passes around this pressure pulse path between the two transducers (piezoelectric crystals) will cause low readings. A minimum of 10 diameters of straight approach into the meter after such minor fittings as elbows or tees is generally adequate provided that a jet or spiraling flow is not introduced. Multiple pumps discharging into a header larger than the pump discharge pipe size, especially if the flow enters the header at less than a 90 degree angle, increasers and multiple elbows in different planes can and do seriously degrade the accuracy and should be avoided in close proximity to the meter.

5. Liquid Limitations - For a transmissive ultrasonic flow meter to operate at all, the pressure pulses must be received by the opposite transducer. The electronics must detect and interpret only the transit time of received pulses transmitted in a straight line from one transducer to the other as only the transit time of these pulses is proportional to flow rate. Pulses received which have been reflected from particle to particle or have been short circuited through the walls of the sensor have longer and shorter times of flight and thus produce large errors. Ultrasonic pulses are absorbed or reflected by various sludges and by microscopic bubbles of air precluding operation.

6. Normal Applications - The transmissive ultrasonic meters are normally utilized for the following municipal applications:

(1) Raw Water
- Wells
- Lakes
- Rivers
- Ponds
- Springs

(2) Water Treatment Plants
- Influent
- Filter Effluent
- Backwash Water
- Plant Effluent
- Filter Spray Wash
- Chemical Make-up Water

(3) Wastewater Treatment Plants
- Raw Sewage
- Return Activated Sludge
- Waste Activated Sludge
- Secondary Settling Tank Supernatant
- Treated Effluent
- Plant Water
- All Tertiary Treatment Flows
- All Supernatant Flows except Mixed Liquor

NOTE: If propeller meters are suitable for the application, and their accuracy of ±2.0% and their rangeability is adequate, they are the most economical meter for the above applications.

Sparling has more than 2,500 ultrasonic meters in service. Even though there are many successful meters in some of the following applications, Sparling's experience dictates that too many misapplications will result from the use of transmissive ultrasonic meters in these services:

(4) NOT RECOMMENDED

- o PRIMARY SLUDGE
- o MIXED LIQUOR
- o AEROBICALLY DIGESTED SLUDGE
- o ANAEROBICALLY DIGESTED SLUDGE
- o DISSOLVED AIR FLOTATION THICKENED SLUDGE AND ITS LIQUID PHASE
- o SEPTIC SLUDGE
- o ACTIVATED CARBON SLUDGE
- o ANY LIQUID WHICH FREE FALLS AND THUSLY ENTRAINS MICROSCOPIC PARTICLES OF AIR.

7. Full Pipe - The meter must be installed in a pipe flowing full.

8. Head Loss - Negligible.

9. Power Consumption - 15 to 40 watts normal. Some manufacturers are higher.

10. Other Ultrasonic Technologies - The sing-around principle for ultrasonic meters was the first technique used. This technique produced a frequency proportional to average flow rate by using each received pulse to trigger the next pulse. Any blockage of a pulse would result in catastrophic errors. Several attempts were made to overcome this weakness. However, none have been successful. This technique has been virtually abandoned.

    The difference time method transmits pulses upstream and downstream across and through the centerline of the pipe. The difference between the upstream and downstream transit times is measured. This time difference is proportional to the average flow velocity. Significant errors are introduced by changes in the speed of sound in the liquid. The speed of sound changes with temperature, viscosity, bulk modules, etc. The inaccuracy of measurement of such short periods of time as these transit times also introduces significant error. The frequency difference method output is unaffected by change in the speed of sound in the liquid, regardless of the cause. (See PDS-560)

IV Doppler Ultrasonic Flow Meters

1. Accuracy - The most reliable data indicates ±2.0% of scale is achievable in the laboratory, but seldom is achievable in field installations. However, most of these sensors are clamp-on devices requiring field calibration. The usual field tests indicate that one should add about 5% to the base error for a total of ±7% or worse. The author's personal analysis indicates it is a rare case in which a better than ±5% field test accuracy is achieved.

2. Rangeability - Most manufacturers do not state a range but rather rate their product as a percent of full scale. As indicated above, a ±7% full scale error results in a ±70% error at 10% of scale flow rate. Many manufacturers emphasize repeatability rather than an accuracy over a specific range for this reason.

3. Repeatability - The best which can be expected is ±0.3% of rate (based on simulated flow conditions).

   Linearity - The best which can be expected is ±0.3% of rate (from 2.0 ft/sec up).

4. Flow Profile Limitations - These devices must be located on the pipe where there is a fully developed velocity profile as they average the flow rate of only that portion of the flow profile penetrated and from which reflected sound is received. In heavy sludges, they would indicate the flow near the surface of the pipe which could be flowing in the reverse direction in some flow profile situations.

5. Liquid Limitations - The liquid must have particles (solids or gas) in suspension in order to operate. As sludges get heavier, the sound is reflected earliest and loudest from particles immediately inside the pipe wall producing an erroneous average flow signal.

6. Normal Applications - Limited to those applications where high accuracy is not required and the range is limited. They serve well for flow/no flow detection.

7. Full Pipe - The meter must be installed in a pipe flowing full.

8. Head Loss - Negligible. No more than the pipe on which it is installed.

V Electromagnetic Flow Meters: (Magmeters)

NOTE; Pitot and probe type magnetic flow meters are not considered herein as their limitations are much more restrictive. As a result, they are seldom used in water and wastewater applications.

1. Accuracy - Accuracy statements for the various magmeters on the market range from ±1.0% of full scale to ±0.5% of rate, usually over a 3:1 range. Below the 3:1 range, a different accuracy statement covers another segment of the range. As the cost increases markedly with improvement in accuracy, selection should be based on application requirements using the least accurate meter required for that particular need. To assure the accuracy of the meter meets the stated accuracy, the meter must be calibrated for at least one flow rate in the range to be used. The flow tests should be made against a primary standard, not a secondary standard.

2. Rangeability - Usually 10:1 or better. However, it varies widely with type and manufacturer. The key to cost effectiveness is to require only that rangeability which the specific application requires. Do not specify a 40:1 range when the need is only for a 3:1 or 5:1 range or it will cost you dearly.

3. Linearity - Excellent. Usually ±0.1%.

4. Flow Profile Limitations - Usually 2 to 3 diameters of straight approach after standard elbows or tees. The electromagnetic flow meter has the least accuracy degradation of any velocity measuring primary device. However, as most magnetic flow meters have characterized coils, center jets should be avoided.

5. Normal Applications - Magmeters have now been applied in almost all water and wastewater flow applications. Their initial cost has discouraged a much wider usage compared to other types of flow meters with more restrictive limitations. They require the shortest straight approach for accurate measurement. They are limited only to liquids which have a minimum conductivity required for the particular design. The normal applications in water and wastewater all have a much higher conductivity than required. Cost reduction breakthroughs are now occuring due to better electronics. As this continues, the magmeter will become the preferred primary flow sensor for many more applications than at present. The magnetic flowmeter is now normally used in the following applications:

(1) Raw Water
- o None

(2) Water Treatment Plants
- o Chemicals
- o Alum Sludge
- o Lime Sludge

(3) Wastewater Treatment Plants
- o Raw Sewage
- o Primary Sludge
- o Mixed Liquor
- o Return Activated Sludge
- o Waste Activated Sludge
- o Aerobically Digested Sludge
- o Anaerobically Digested Sludge
- o Dissolved Air Flotation Thickener Sludge and its liquid phase
- o Chemicals
- o Activated Carbon Sludge
- o Tertiary Sludge
- o Septic Sludge

7. Full Pipe - The meter must be installed in a pipe flowing full.

8. Head Loss - Negligible. No more than an equivalent section of pipe.

9. Power Consumption - Ranges from 6 watts to several hundred watts, depending on type and size. Power consumption in some models, especially those with AC coil excitation, is a major factor in cost effectiveness evaluation.

10. Accuracy Degradation - If the liquid deposits a conductive coating on the inside of the flow tube, the meter electrodes will short out and eventually the meter will read zero regardless of what the flow is.

    If the liquid deposits a non-conductive coating on the inside of the flow tube, a part of the voltage developed by the flow of the liquid through the magnetic field will drop across the non-conductive coating and not be measured at the pre-amplifier. Several methods have been developed to remove non-conductive coatings from the electrodes. The first developed were wipers, both manual and motor operated. These have given way to more effective methods. The current state-of-the-art is either to use ultrasonic cleaners or a high input impedence pre-amplifier. If ultrasonic cleaners are used, they should be continuous to be effective. They will not completely remove greases. Ultrasonic cleaners add a considerable amount to the power consumption and therefore to the operating cost of the flow meter.

CHLORINE DIOXIDE IN WATER & WASTEWATER TREATMENT

Dr. Marco Aieta, Technical Director
Rio Linda Chemical Company
Sacramento, California

I. Generated Chlorine Dioxide

A. Physical Properties

1. Green to red gas, pungent odor, stable free radical.

2. Unstable at high concentration in gas phase, cannot be compressed, must be generated on-site.

3. In water, does not hydrolize as does chlorine, exists as a dissolved gas like oxygen, speciation of ClO_2 not effected by pH, more soluble than chlorine, but more volatile.

B. Chemical Properties

1. Does not substitute into humics to form THMs (very little TOX), but does oxidize these compounds, resulting in THM precursor destruction.

2. Does not react with ammonia or primary amines, organic or inorganic.

3. Destroys phenolics and chlorophenolic compounds that are present in source waters or formed by pre-chlorination.

4. Destroys taste and odor (especially musty and fishy odors) associated with impounded or polluted water supplies.

5. Iron and manganese oxidation and removal (filtration).

6. Is effective in some color control and removal.

7. Aids in coagulation and turbidity removal.

8. Provides a measurable residual.

9. Will oxidize sulfides for T & O.

10. Can disproportionate at high pH.

$$2\ ClO_2 + 2OH^- = ClO_3^- + ClO_2^- + H_2O$$

C. Biological Properties

1. Chlorine dioxide is a very strong bactericide

   $O_3 > (\text{or} =) ClO_2 > HOCl > OCl^- \gg \text{Chloramines}$
   (Hoff, AWWA, January 1981)

2. Chlorine dioxide is also a strong viricide

   $O_3 > (\text{or} =) ClO_2 > HOCl \gg OCl^- \gg \text{Chloramines}$
   (Drinking Water and Health, Vol 2)

3. Chlorine dioxide is effective against protozoan cyst; with the emerging Giardia Lamblia problem, this may be an important consideration.

   $O_3 = ClO_2 > HOCl$

4. Chlorine dioxide will control in-plant algal and slime growth; resulting in longer filter runs and eliminating a potential source of taste and odor problems.

5. Chlorine dioxide or its reaction by-products (organic and inorganic) have never been implicated as mutagenic nor carcinogenic in either cell culture assays or animal studies.

6. Chlorine dioxide and reaction by-products chlorite and chlorate have shown some acute and/or chronic toxicity in laboratory animals at high doses (> 100 mg/L). All human laboratory and epidemiological studies at doses of up to 25 mg/L for 60 days (1 litre per day) have shown no effects on the exposed individuals.

7. Epidemiological studies have shown no effects on groups exposed to 5-8 mg/L of chlorite over a several month period.

8. The EPA suggest a total residual chlorine dioxide and chlorite (and chlorate ?)of 1.0 mg/L at the tap.

9. Tumor initiation study -

Tumor Initiation by Reaction Products of Various Disinfectants[a] After 20 Weeks of Promotion with PMB[b]
(From Bull, JAWWA May 1980, p302)

SAMPLE	CONCENTRATION FACTOR	NO. ANIMALS with TUMORS	TOTAL TUMORS	% ANIMALS with TUMORS
Non-disinfected[c]	120	0/25	0	0
Chlorine	106	4/25	5	20
Chloramine	142	5/25	8	32
Chlorine dioxide	168	0/25	0	0
Ozone	186	7/25	9	36
Saline	-	1/25	1	4
7,12-dimethyl-benzo(a)anthracene	-	16/25	35	140

[a] Substrate was settled, coagulated and filtered Ohio River water. The total dose was 1.5 mL (6 x 0.25 mL) given subcutaneously at the concentration factor indicated.

[b] PMA= Phorbol myristate acetate applied at the dose of 2.5 µg, three times weekly.

[c] After treatment, water was subjected to reverse osmosis with cellulose acetate to the level indicated by the concentration factor (initial volume/final volume).

II Application Technology - Drinking Water

A Philosophy

Use chlorine dioxide at the appropriate point in the treatment sequence and at the lowest level possible to achieve the desired result. Chlorine dioxide is not necessarily a replacement for chlorine or chloramines but its special properties can be used to the best advantage by integrating it into existing treatment.

B. Application - Primary Disinfection/THM Control

NOTE: On THM regulation - Current THM regulation is 100 µg/L. Current European THM regulation is 5-25 µg/L. Joe Cotruvo of the USEPA Office of Drinking Water Regulations stated at the Water Chlorination Conference (1984) and at the AWWA Annual Convention in Dallas (1984) that the regulation is under review and may be changed (lowered) for the revised Primary Drinking Water Standards to become effective 1986.

1. Dose chlorine dioxide at plant influent at sufficient level to achieve 0.1-0.5 mg/L chlorine dioxide in the clear well. Use free chlorine for distribution system residual maintenance.

Advantages -

a. No THM (very little TOX) formation during precursor removal.

b. Strong primary disinfectant for 1-6 hour contact time.

c. Can be used only as needed during seasonal THM/taste and odor problems.

d. Does not alter distribution system disinfectant residual.

e. Taste and odor control.

f. In-plant control of micro and macro biofouling.

g. Turbidity removal and coagulation enhancement.

h. Least expensive mode of chlorine dioxide use.

Problems -

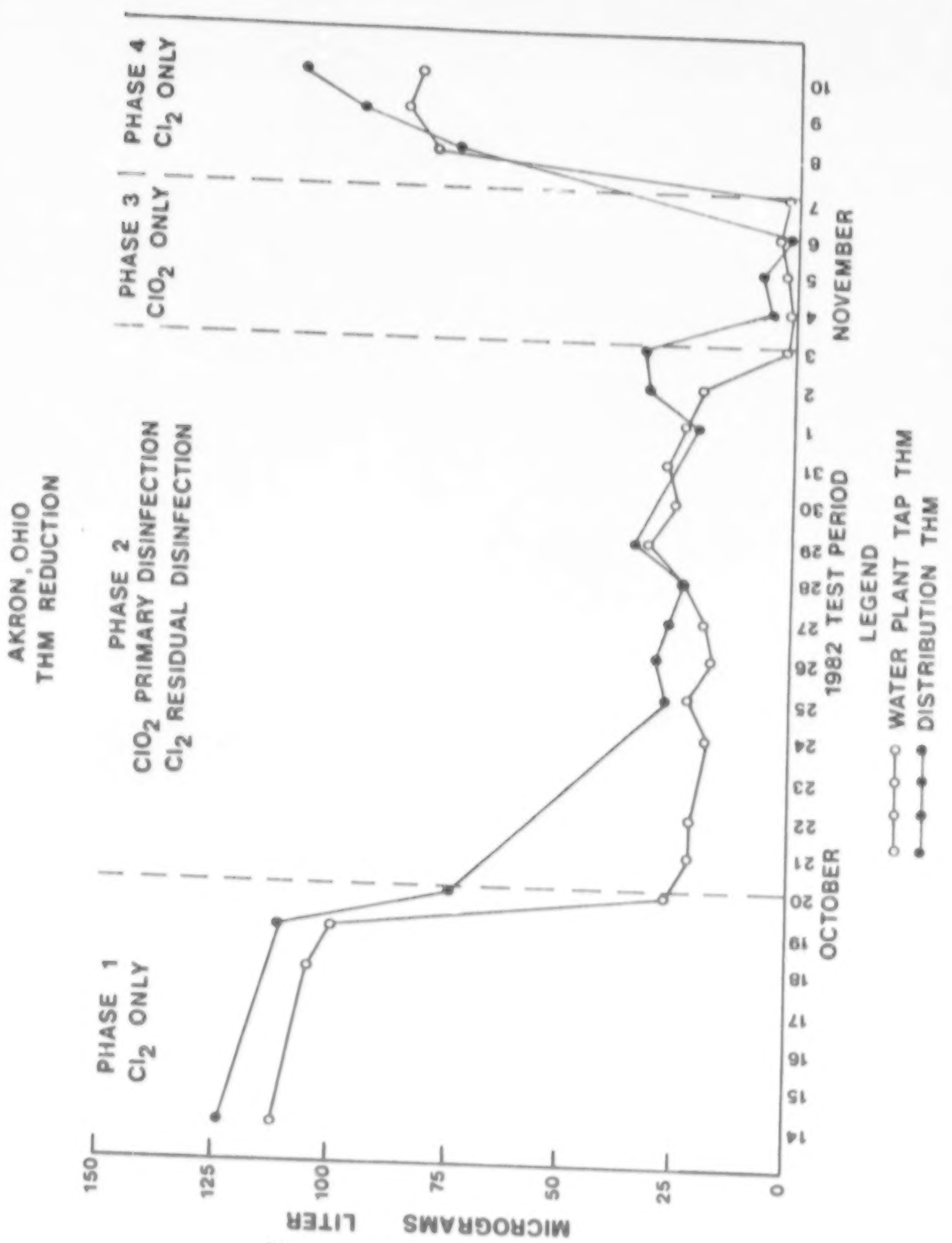
a. If THM precursors remain at sufficient levels, free chlorine in the distribution system may cause THM levels to exceed the 100 μg/L (or upcoming lower standard). Solution is to use chloramines as distribution system residual disinfectant.

Note: Chloramines are excellent for maintaining a long - lived residual. However, chloramines are slow acting disinfectants and weak viricides. In most states, a primary disinfectant (free chlorine or chlorine dioxide) is required prior to the addition of chloramines. In addition, increased monitoring and public notification for dialysis patients and facilities, and tropical fish producers is required. If organic-N compounds are present, less effective organic chloramines may be formed. Taste and odor problems may develop with the use of chloramines.

b. If chloramines as distribution system disinfectant pose problems and free chlorine results in excess THM formation, use chlorine dioxide as the distribution system disinfectant, but maintain total of chlorine dioxide, chlorite and chlorate at 1 mg/L at the tap.

C. Case Histories

1. Akron - THM Reduction
   - Taste and odor control


AKRON, OHIO
THM REDUCTION
PHASE 1
Cl_2 ONLY
PHASE 2
ClO_2 PRIMARY DISINFECTION
Cl_2 RESIDUAL DISINFECTION
PHASE 3
ClO_2 ONLY
PHASE 4
Cl_2 ONLY
TRIHALOMETHANES (THM)
MICROGRAMS
LITER
0
25
50
75
100
125
150
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
1
2
3
4
5
6
7
8
9
10
OCTOBER
NOVEMBER
1982 TEST PERIOD
LEGEND
WATER PLANT TAP THM
DISTRIBUTION THM

a. Treatment sequence:

Pre-disinfectant, alum coagulation, flocculation, sedimentation, mixed-media filtration, post-chlorination.

Disinfectant Dose:

Phase	Primary Disinfection	Residual Disinfection
1	7.5 mg/L Cl_2	1.5 mg/L Cl_2
2	2.0 mg/L ClO_2	1.0 mg/L Cl_2
3	2.2 mg/L ClO_2	0.2 mg/L ClO_2
4	6.5 mg/L Cl_2	1.0 mg/L Cl_2

b. Results:

1. THM profile using $ClO_2 + Cl_2$
2. THM profile using ClO_2 only

2. Edmonton - Taste and Odor Control
   - Giardia Lamblia
   - In plant bio-control

b. Results:

1. Complaints reduced.
2. Algal and slime growths in flocculators, clarifiers stilling basins and filters absent.
3. Significant decrease in Giardiasis - related??
4. Using ClO_2 year round.
5. Total O & M cost < ¢ / 1000 gallons

III Generation Technology and Residual Measurement

A. Relevant Chlorine Sepcies

Chlorine Dioxide	ClO_2
Chlorine	Cl_2
Hypochlorous Acid	HOCl
Hypochlorite	OCl^- (NaOCl or $Ca(OCl)_2$)
Chlorite	ClO_2^- ($NaClO_2$)
Chlorate	ClO_3^- ($NaClO_3$)

B. Chlorine Hydrolysis reaction

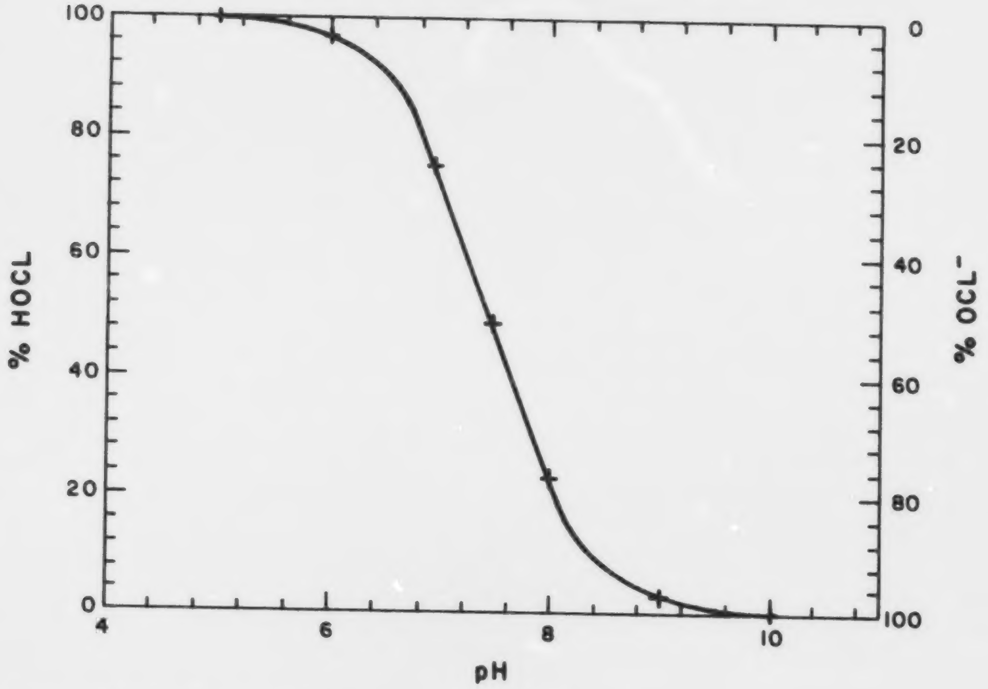
$$Cl_2(aq) + H_2O = HOCl + H^+ + Cl^-$$

Equilibrium Expression

$$K_H = \frac{(HOCl)(H^+)(Cl^-)}{(Cl_2)}$$

Dissociation of Hypochlorous Acid

$$K_a = \frac{(OCL^-)(H^+)}{(HOCL)} ; \qquad pK_a\ (25°C) = 7.43$$



Dissociation of Hypochlorous Acid in Water at 25°C

C. Reactions of Chlorine Species with Sodium Chlorite

1. To yield chlorine dioxide

$$Cl_2 + 2\ NaClO_2 \rightarrow 2\ ClO_2\ NaCl$$

2. To yield chlorate

$$HOCl + NaClO_2 + OH^- \rightarrow NaClO_3 + Cl^- + H_2O$$

3. Reaction mechanism - experimental observations.
   a. The reaction between chlorite ion (or chlorous acid) and chlorine (in acid or neutral solution) is second order overall, being first order in both chlorine and chlorite;

b. Acidic pH values favor the formation of chlorine dioxide, whereas at neutral and alkaline pH, chlorate is the primary reaction product;

c. For a given pH value, an increase in chlorite concentration results in relatively more chlorine dioxide production;

d. Higher chloride ion concentrations favor the formation of chlorine dioxide relative to chlorate, especially at acidic pH and;

e. Proportional increases in all reactant concentrations favor the formation of chlorine dioxide relative to chlorate.

i.e. Need to react the concentrated reactants under conditions where molecular chlorine is the predominant chlorine species present to achieve high yields of chlorine dioxide.

Step 1:

$$ {}^*Cl_2 + ClO_2^- = \begin{array}{l} [{}^*Cl - Cl - O] \\ \qquad\qquad\ \backslash\ O] \end{array} + {}^*Cl^- $$

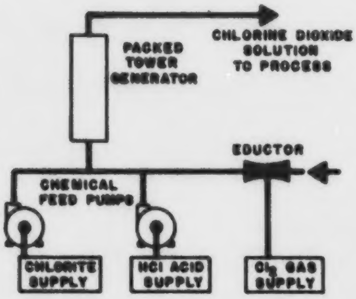
Step 2a: Production of chlorine dioxide

$$ 2\begin{array}{l} [{}^*Cl - Cl - O] \\ \qquad\qquad\ \backslash\ O] \end{array} = 2ClO_2 + {}^*Cl_2 $$

Step 2b: Production of chlorate

$$ \begin{array}{l} [{}^*Cl - Cl - O] \\ \qquad\qquad\ \backslash\ O] \end{array} + H_2O = ClO_3^- + {}^*Cl^- + 2H^+ $$

D. The Competition


CHLORINE DIOXIDE SOLUTION TO PROCESS
PACKED TOWER GENERATOR
EDUCTOR
CHEMICAL FEED PUMPS
CHLORITE SUPPLY
HCl ACID SUPPLY
Cl_2 GAS SUPPLY

1. Three chemical
   Use acid to lower pH to favor molecular chlorine.

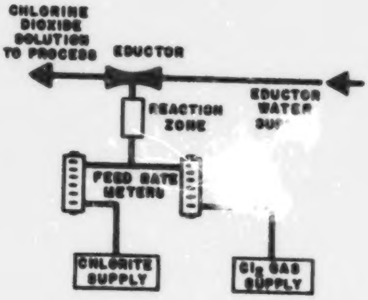
2. Excess chlorine

Use excess chlorine to lower pH to favor molecular chlorine; results in chlorine dioxide solution containing significant amounts of chlorine.

3. French loop

Use a supersaturated chlorine solution to achieve molecular chlorine/chlorite reaction; difficult to control, slow to respond, maintenance problems, expensive.

E. The Rio Linda System


CHLORINE DIOXIDE SOLUTION TO PROCESS
EDUCTOR
EDUCTOR WATER SU
REACTION ZONE
FEED RATE METERS
CHLORITE SUPPLY
Cl_2 GAS SUPPLY

1. Achieves the appropriate reaction conditions to favor chlorine dioxide formation while supressing chlorate formation without the use of acid or excess chlorines.

2. Advantages

   a. Safety
   b. Low Capital investment
   c. Operational flexibility
   d. No acid required
   e. No chemical feed pumps
   f. Low maintenance

3. Specifications

   a. Capacity
   30 - 3000 pounds chlorine dioxide per day

   b. Support Facilities Required
   Chlorine gas source
   Water supply for eductor system
   Electrical power

c. Control Available
Manual
Automatic - Flow paced or Compound loop

4. ******* Cost Savings of 95% yield vs. 85% yield *******

Assumptions:

15 MGD Flow
1 m/L ClO_2 dose
25% $NaClO_2$ solution - \$ 4.75/gal
\$ 1.84/lb of 100% $NaCOl_2$

Generator

Size - 140 lb ClO_2 / day
Usage - 125 lb ClO_2 / day
Capital cost
- RLC = $10,300 incl. training

Sodium Chlorite Usage and Cost:

at 95% yield = 68 gal/day
= $ 325/day
= 2.2 ¢ / 1000 gal

at 85% yield = 76 gal/day
= $ 362/day
= 2.42 ¢ / 1000 gal

Savings:
= $ 37/day
= $ 1110/month
= $ 13505/year

5. Start-up and Training

a. Training of Operating Personnel --

1. Check-out of Generator Installation.
2. Physical Properties of Chlorine Dioxide, Chlorine, Chlorite.
3. Chemistry of Chlorine Dioxide Generation.
4. Optimization of Generator Performance.
5. Maintenance of Generation Systems.
6. Safety Considerations in Operation and Chemical Handling.

b. Training of Laboratory Personnel --

1. Physical Properties of Chlorine Dioxide, Chlorine, Chlorite.
2. Chemistry of Chlorine Dioxide Generation, Lab and Plant Scale.

3. Sampling for Chlorine Dioxide Determinations.
4. Analytical Procedures for Measuring Yields and Residuals.
5. Safety Considerations for Chlorine Dioxide in the Laboratory.

F. Comparison of Chlorine Dioxide and Ozone Costs

	Chlorine Dioxide	Ozone[a]
Plant Size	15 MGD	15 MGD
Generator Capacity	250 PPD	400 PPD
Dose (operational)	1.0 mg/L	1.5 mg/L
Dose (maximum)	2.1 mg/L	3.0 mg/L
Initial Capital Cost	$15,000	$750,000
Treatment Costs in ¢ / 1000 gallons -		
O&M Cost[b]	2.20	1.80
Capital Costs[c] (10%, 20 years)	0.03	1.59
TOTAL COSTS	2.23	3.39 (3.8)

---

[a] Ozone costs from "The Economics of Ozonation at Monroe" by W.L. LePage, Ozone: Science and Engineering, Vol. 5, pp 245 - 257, 1983.

[b] Includes spare parts, electricity, cooling water and labor.

[c] Includes overhead, amortization and insurance.

IV Stabilized Chlorine Dioxide

A. Physical Properties

1. Aqueous solution, slight chlorinous odor.
2. Stable for 12 months.
3. Available in 6% and 25% strengths.

B. Chemical Properties

1. Complex in equilibrium with chlorine dioxide and chlorite
$$Cl_2O_4^- \leftrightarrow ClO_2 + ClO_2^-$$
2. Releases chlorine dioxide slowly at neutral and alkaline pH.

3. Rate of reaction and release with decreasing pH.

C. Biological Properties

1. Slow acting biocide, but effective bacteriastat.
2. NOT intended for use as a disinfectant.
3. Effective in the control of slime in cooling towers and closed conduits.

V. Application Technology - Wastewater

A. Sulfide Control in Sewage Collection Systems

1. Problems with sulfides in newer systems

   a. Health hazard to operations and maintenance personnel
   b. Severe and rapid deterioration of collection lines and manhole structions due to sulfuric acid corrosion
   c. Corrosion of machinery and metal surfaces
   d. Odors at treatment plant and throughout the collection system

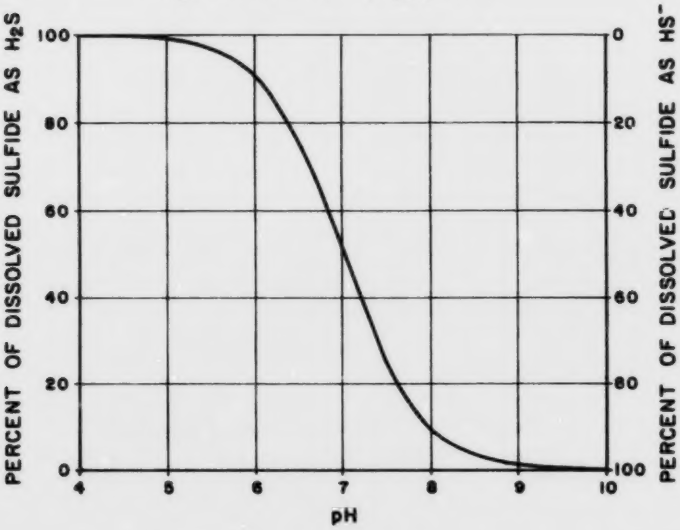
2. Sulfur cycle in sewer systems

   a. Production of sulfides

   $$SO_4^{=} + \text{organic matter} \xrightarrow{\text{(anaerobic bacteria)}} S^{=}\ H_2O + CO_2$$

   b. Dissociation of hydrogen sulfide

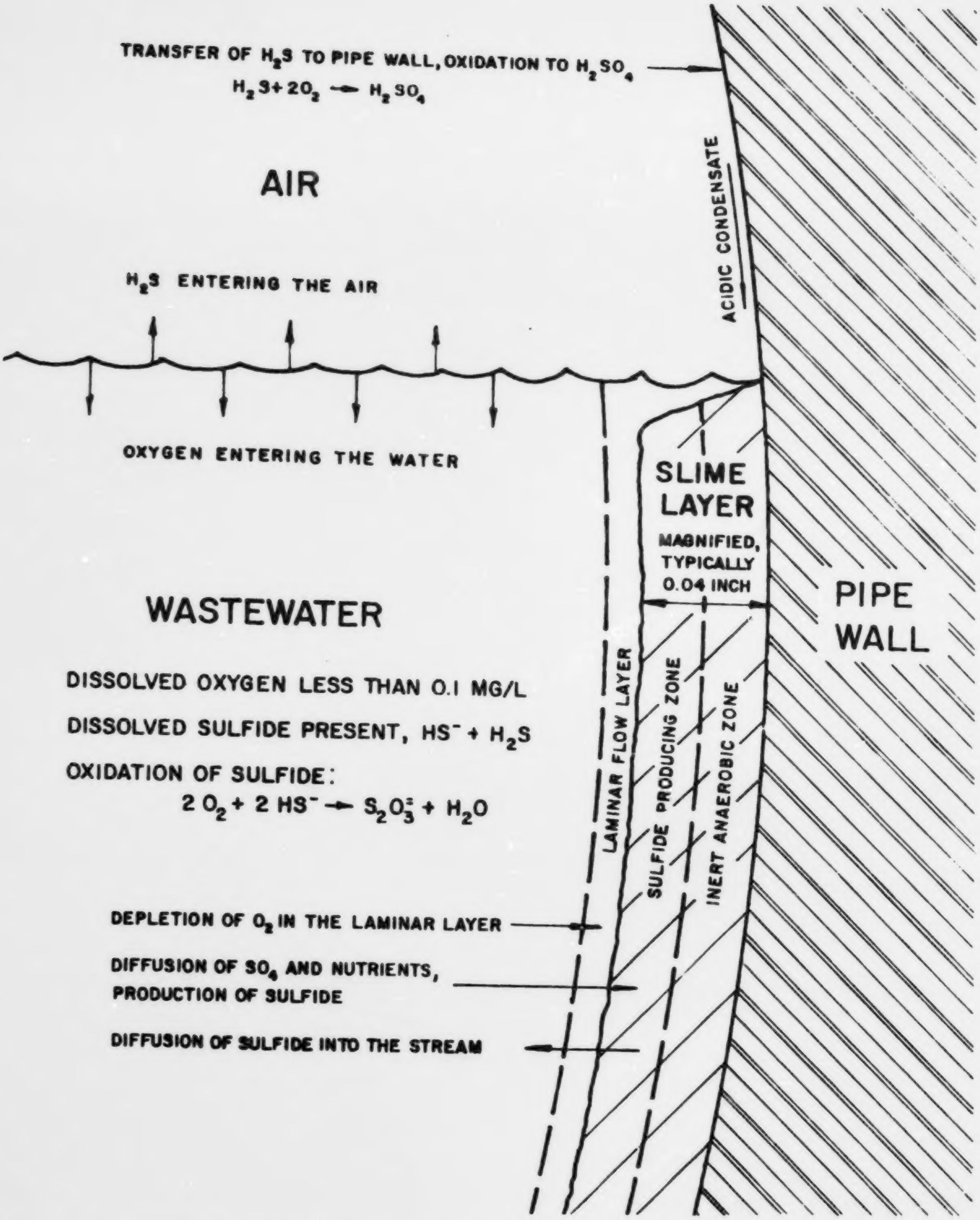
   $$H_2S \leftrightarrow H^+\ HS^- \ ;\ pK_a = 7$$



DISSOLVED SULFIDE EQUILIBRIUM

   c. Oxidation of sulfides by bacteria

   $$H_2S + 2O_2 \xrightarrow{\text{(aerobic bacteria)}} H_2SO_4$$


TRANSFER OF H_2S TO PIPE WALL, OXIDATION TO H_2SO_4
$H_2S + 2O_2 \rightarrow H_2SO_4$
AIR
ACIDIC CONDENSATE
H_2S ENTERING THE AIR
OXYGEN ENTERING THE WATER
SLIME LAYER
MAGNIFIED, TYPICALLY 0.04 INCH
PIPE WALL
WASTEWATER
DISSOLVED OXYGEN LESS THAN 0.1 MG/L
DISSOLVED SULFIDE PRESENT, $HS^- + H_2S$
OXIDATION OF SULFIDE:
$2\,O_2 + 2\,HS^- \rightarrow S_2O_3^= + H_2O$
LAMINAR FLOW LAYER
SULFIDE PRODUCING ZONE
INERT ANAEROBIC ZONE
DEPLETION OF O_2 IN THE LAMINAR LAYER
DIFFUSION OF SO_4 AND NUTRIENTS, PRODUCTION OF SULFIDE
DIFFUSION OF SULFIDE INTO THE STREAM

PROCESSES OCCURRING IN SEWERS UNDER SULFIDE BUILD-UP CONDITIONS

d. Oxidation of sulfides by stabilized chlorine dioxide

i) the stabilization equilibrium

$$Cl_2O_4^{\,-} \leftrightarrow ClO_2 + ClO_2^{\,-}$$

ii) reactions with sulfides (H_2S or HS^-)

$$2H_2S + 2ClO_2 \rightarrow 2HCl + H_2SO_4 + S^\circ\ (aq)$$

iii) reactions that release chlorine dioxide

$$ClO_2^{\,-} + H_2S \rightarrow HClO_2 + HS^-$$

or: $ClO_2^{\,-} + HCl \rightarrow HClO_2 + Cl^-$

or: $2ClO_2^{\,-} + H_2SO_4 \rightarrow 2HClO_2 + SO_4^{\,=}$

then: $HClO_2 \rightarrow 4ClO_2 + HCl + 2H_2O$

iv) benefits

- Effective control of odors and deterioration of concrete pipes
- Chlorine dioxide persists in the system resulting in few application points
- Removes sulfides at the point of sulfide production
- Destroys sulfur reducing bacteria at site of sulfide production
- Effective in removing slime layer
- Simplified chemical handling in the field

3. Application of Stabilized Chlorine Dioxide for Sulfide Control

a. Sulfide survey of system over 24 hour period to identify problem areas and to identify time of highest sulfide production.

b. Continuous dosing in problem areas (especially forced mains) at 10-30 gallons of stabilized per million gallons of flow until control is achieved.

c. Decrease dosage to achieve control at minimum chemical feed.

d. Monitor system to insure adequate treatment and adjust dosage accordingly.

NOTE; Each system will be different in the amount and location of sulfide production and in the amount of treatment required. Some of the factors that influence sulfide production and control are BOD loading of the system; sulfate and oxygen concentration of the waste stream; sewage pH, alkalinity and temperature; flow velocity and turbulence; pipe size, residence time and depth of flow.

B. Airborne Odor Control

1. Wet Scrubbers

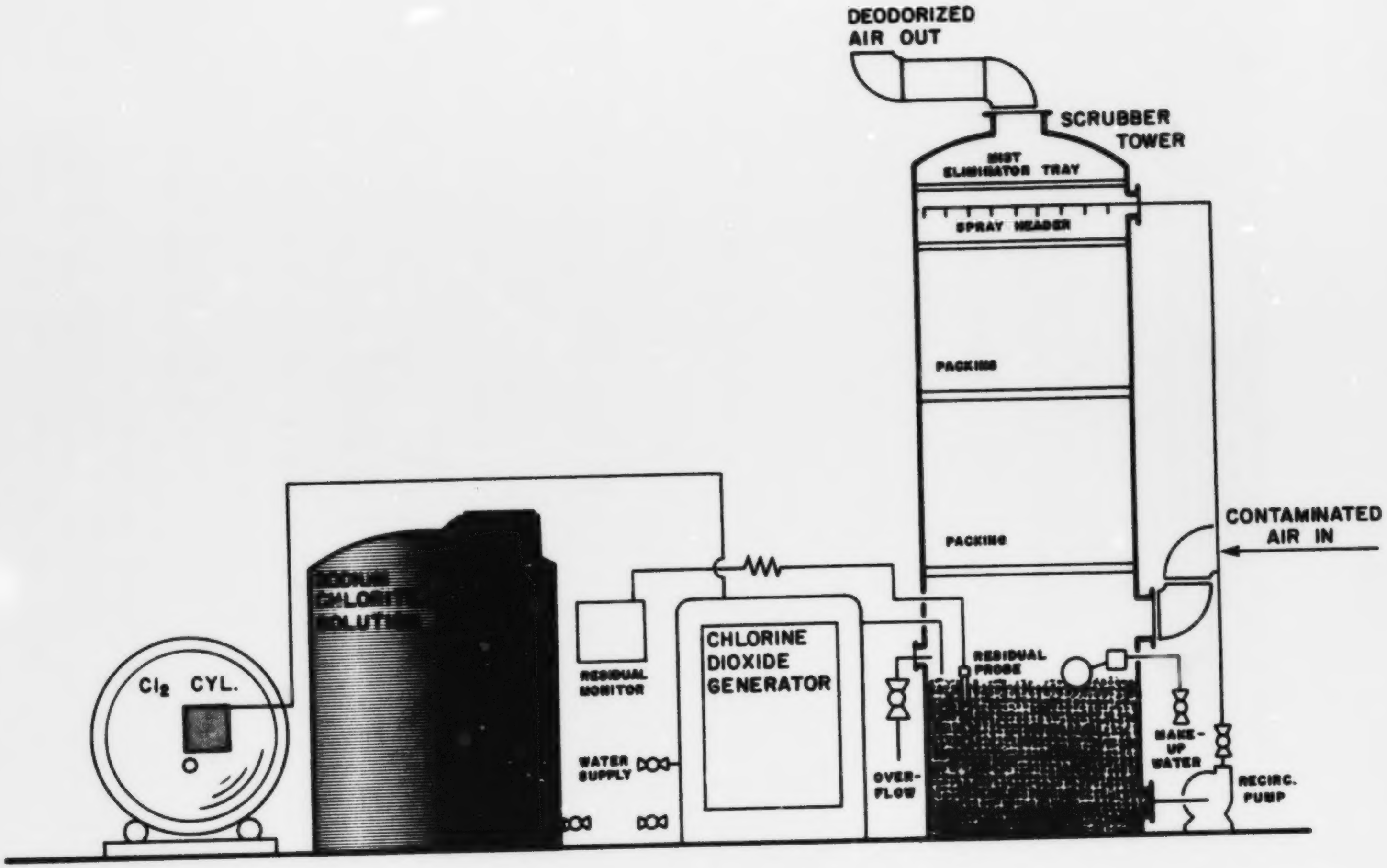
    a. Generated chlorine dioxide is used for high loadings and/or short contact times.
    b. Stabilized chlorine dioxide for highly reactive organic acids in low concentrations and/or low pH systems.

2. Dry Scrubbers

    a. Use a dry release chlorine dioxide that is activated by volatile organic acids or hydrogen sulfide.

VI Summary - Rio Linda, The Chlorine Dioxide Technology Company

- → Sound Engineering of the Appropriate Chemistry
- → Appropriate Application Technology
- → Complete Training and Support
- → Most Cost Efficient Chlorine Dioxide System Available


DEODORIZED AIR OUT
SCRUBBER TOWER
MIST ELIMINATOR TRAY
SPRAY HEADER
PACKING
PACKING
CONTAMINATED AIR IN
RESIDUAL PROBE
MAKE-UP WATER
RECIRC. PUMP
OVER-FLOW
CHLORINE DIOXIDE GENERATOR
RESIDUAL MONITOR
WATER SUPPLY
SODIUM CHLORITE SOLUTION
Cl_2 CYL.

Chlorine dioxide treatment

USE OF POTASSIUM PERMANGANATE IN WATER AND WASTEWATER TREATMENT

John Bol, Supervisor
Field Services, Carus Chemical Co.
LaSalle, Illinois

INTRODUCTION

Potassium permanganate has been the principal chemical product of Carus Chemical company since its founding in 1915. It is marketed under the trade name CAIROX®. Potassium permanganate is a strong oxidizing agent and is used in many industries. It is used to purify drinking water, treat wastewater, synthesize and purify chemicals, condition metal for subsequent acid cleaning, clean industrial exhaust gases, plus a number of other applications.

Municipal, Industrial, and Domestic Water Treatment

Potassium permanganate is being used quite extensively for the treatment of drink water. The major applications are for the control of odors and tastes, and for the oxidation of iron, manganese, and hydrogen sulfide. Most recently, the Federal EPA has recognized potassium permanganate as one of the alternate oxidants that can be used in place of pre-chlorination to minimize the formation of trihalomethanes in municipal drinking water. The EPA has also approved the use of CAIROX® potassium permanganate for the control of algae in water treatment plants. A short discussion of each of these applications follows.

Municipal Water Treatment

Municipal water systems derive their drinking water from two sources, ground and surface. Surface supplies are generally rivers, man-made impoundments, or natural lakes. Depending upon climatic conditions, natural and/or industrial activity, and recreational uses, the surface supplies can become contaminated with organic and inorganic materials making the water unfit to drink. Tastes, odors, color, iron, manganese, and other contaminants must be treated before the water can be made palatable and bacteriologically safe.

Well or ground water are normally free of industrial contamination, but can contain high concentrations of dissolved minerals and metals. While generally not harmful or toxic (except for high concentrations of hydrogen sulfide), this dissolved matter can make the water aesthetically unpleasing. There is a concern that ground waters may become more contaminated as a result of "dumped" chlorinated organics and leachate from improperly prepared landfills.

Municipalities provide treatment with two different filtration techniques, pressure or gravity. The source will also affect the type of plant. State regulations usually dictate that surface supplies provide gravity filtration, while well supplies can have either gravity or pressure systems. Since permanganate reacts to form an insoluble by-product, manganese dioxide, it can only be used in plants having filtration, either gravity or pressure.

Algae or algae-related activity has been cited by the American Water Works Association as being responsible for 75% of the taste and odor problems encountered by cities using surface water as their source. Permanganate reacts with a substantial number of compounds produced by algae, as well as with the algae itself. Oftentimes, these algal metabolic products create tastes and odors described as "fishy, musty, cucumber, earthy, grassy, and septic." If not treated and removed these odors and tastes can create doubt in the consumer's mind as to the safety of the water. The dosage normally ranges from 2 to 24 pounds of $KMnO_4$ per million gallons of water, when treating taste and odor.

There are a number of water supplies along rivers which are plagued with industrial as well as natural contamination. Organics such as phenol can create serious taste and odor problems. Many municipal systems are using permanganate successfully to control organics along river supplies subject to industrial contaminants.

Many cities which take their water from impoundments experience manganese in the raw water. This manganese comes primarily from decayed vegetation. While there are some other oxidation techniques which can be used to oxidize this manganese, potassium permanganate because of its fast-acting oxidation power, is the oxidant of choice.

During the last several years, the industry along with the EPA has been studying the chlorinated organics found in drinking water. While some are present from industrial contamination, a greater majority were being produced in the treatment process because of the addition of chlorine for disinfection. The EPA and American Water Works Association recently agreed to 100 ppb (parts per billion) standard for the four trihalomethanes, which are chloroform, dichloro-bromomethane, dibromo-chloromethane, and bromoform.

In addition to the major applications, permanganate is also being used to control slime, remove color, control Corbicula (an Asian clam), and to assist in the coagulation process. It is an integral part of municipal and industrial drinking water treatment.

Domestic Water Treatment

In domestic or home water filters, potassium permanganate is essential. The filters, used mainly for iron, manganese, and hydrogen sulfide removal, are supplied by Culligan, Servi-Soft, Water Maid, Lindsay, and many other water conditioning firms. The application of $KMnO_4$ is for the regeneration of the greensand media in these filters. This is done either by the home owner or by the filter supplier in his shop. Home owners, who are not on municipal supplies and must use their own wells, require permanganate to keep their water free of these unwanted contaminants.

Summary

To sum up the use of permanganate for water treatment, potassium permanganate is recognized by municipalities, industries, home owners, and regulatory agencies as an extremely valuable and important chemical in the quest to produce drinking water of unquestionable quality.

Municipal and Industrial Wastewater

The major application of potassium permanganate in municipal wastewater systems is for the oxidation of the toxic compound, hydrogen sulfide. This obnoxious gas is produced both in the collection systems and in the plant during wastewater treatment. Many industries using sulfites, sulfur dioxide, and other sulfur compounds in their process, can also end up with substantial concentrations of hydrogen sulfide in the wastewater. This is very common in pulp and paper mills. In addition to sulfides, other organic products such as phenols and amines can be present in industrial wastewater streams. Potassium permanganate is applied to control many such pollutants.

Researchers found that the addition of free chlorine to the raw water as the first treatment step, was the main cause in the production of trihalomethanes. If the water could be coagulated prior to chlorination, the precursors of these THMs could be substantially reduced. Therefore, by moving the point of chlorination, this problem could be for the most part controlled. However, other problems normally solved by the chlorination of the raw water, now require an alternate oxidant application. The EPA recommends the use of potassium permanganate as one of the alternate oxidants to be used in place of pre-chlorination. Many water utilities have found that by using permanganate in the pre-treatment and moving the point of chlorination, they could meet the 100 ppb standard for THMs. Treating raw water reservoirs with permanganate, as an algicide or for taste and odor control is an effective technique.

A city in Colorado recently found that by applying 1/2 mg/L of potassium permanganate to their raw water reservoir, they could solve a filter plugging problem. They have successfully used the oxidant three times during the last two years.

Many municipalities using well water have problems with iron and manganese. Some also have the additional problem of hydrogen sulfide. A successful process using potassium permanganate ahead of a pressure greensand filter is being applied in both large and small supplies.

Manganese treated greensand is a special filter media which is mined in New Jersey and activated using potassium permanganate. During use, the oxidation potential of this media is used up and must be regenerated with potassium permanganate solution. This process for iron and manganese removal is an essential pre-treatment for brackish waters if reverse osmosis is used. The RO membranes can easily become plugged if the iron and manganese is not removed.

The area of greatest permanganate interest, at the present time, is its application into wastewater sludge. Sludge processing can be odorous because of the nature of the material which is being concentrated for dewatering, and the type of processing which is being employed. In most cases, the solids are separated from the liquid portion of the wastewater stream, and concentrated. In the concentrating process, the sludge can start to become anaerobic, septic, or "sour." When this happens, sulfides are produced in the sludge. When it is finally processed, these sulfides volatilize into the atmosphere. Not only are they abnoxious (the rotten egg odor), but at higher concentrations they can be extremely lethal. A recent case in California discusses the death of several municipal employees caused by hydrogen sulfide.

CAIROX® potassium permanganate can be applied just ahead of the dewatering process to control the H_2S. The dosage ranges from about 1 to 12 pounds per dry ton of sludge processed. In most cases, permanganate is the most cost-effective method of controlling hydrogen sulfide. Added benefits of improved dewatering also have been reported by permanganate customers.

Another area for permanganate application in wastewater is in the collection system. If wastewater is allowed to become anaerobic, hydrogen sulfide can be produced in the system and cause odor problems in residential areas, as well as at the headworks of the treatment plant. Obviously, this will create some disgruntled citizens, as well as create potentially hazardous working conditions for municipal sewerage employees. To solve this problem, an oxidant should be introduced into the system. The two major products being used are potassium permanganate and hydrogen peroxide. The choice is really dependent on costs, ease of application, severity of the problem, and effectiveness of the particular oxidant in that particular system.

In addition to direct injection of the permanganate to the wastewater, another method of odor control is used by some municipalities especially in the treatment plant buildings. The air from the buildings housing various treatment process steps is collected and put through air scrubbers. These scrubbers can use several different oxidants in the scrubber water including potassium permanganate. As the scrubber water comes into contact with the odorous gases, the contaminants are absorbed into the scrubbing solution and then react with the potassium permanganate in the solution. Thus, the odorous gases, mostly H_2S, are scrubbed out of the plant air and the air can now be discharged to the atmosphere or be recycled in the building.

In addition to the municipalities there are a substantial number of industries and government bases which use permanganate in the wastewater systems to remove contaminants other than hydrogen sulfide. The airline maintenance industry uses substantial quantities of CAIROX® to oxidize phenols in the wastewater from the overhaul section. These phenols were in the paint stripping formulations.

Besides phenol, other pollutants being oxidized by permanganate include TMA and MEA in California; a thio phosphorous compound in South California; phenol-formaldehyde in upstate New York; molybedenum in Colorado; chelated heavy metals in Missouri; and manganese in acid mine drainage. In some of these situations, permanganate is the only oxidant that works, according to the customers.

FIBER OPTIC APPLICATIONS IN CLARIFIERS

Herb Zinger, Utilities Superintendent
Town of Castor

I would like to start by giving you a quick overview of our water plant, stressing some of its peculiarities, some of the changes we made, that really helped, and then discuss in length our fiber optic application, along with some slides.

A whole new plant was tendered in 1975, and because of unexpected very high tenders, a scaled down, integrated design was constructed. This initiated a long line of problems, right from start of construction on into operation.

The new treatment facility was connected to new pumps, installed in the old plant, and to existing inadequate storage. This 60,000 gallon tank under the pumps, along with a new 100,000 gallon above ground tank, that must be introduced into the system manually, represents up to two days supply, when demand is low, and only one day when demand is high.

This limited clearwater storage has necessitated 24 hour automatic on-off operation of the plant, to keep the storage always topped off, to ensure as much water under the pumps as possible at all times, whether the plant is manned or not.

Stop-start operation of the plant, along with high color, and very low turbidity of the raw water, creates among other problems, a very unstable sludge blanket in the upflow clarifier, especially during spring and fall raw water turn over.

The blanket will easily rise and flow over into the filters, plugging them completely, or at best shortening their runs. This sometimes leaves us dangerously short or water.

A piece of equipment we fabricated and installed, that proved very helpful, in this situation was an electric eye, with fiber optic carriers.

We first tried an eye that shone down into the water, and was transmitted back with an underwater reflector. This did not work due to light refaction on the surface of the water, intermittent floating material, and inability to adjust the unit under these circumstances.

We then came up with an electric eye, fiber optic application. We were able to get a small adjustable eye light source, complete with pilot light in a unit about the size of a small match box, to which were attached two fiber optic tubes, in our case about three feet long. To make the application convenient we mounted this unit in a piece of 1 1/4" A.B.S. D.W.V. pipe, to make a probe, that could be raised and lowered into the clarifier.

This worked wonderfully well, and for a cost of only about $1,500.00.

When the blanket came up and flowed between the ends of the fiber optics, the plant shut down through relays and a timer. This gave the blanket time to subside before the plant started up again.

During extended water make up, the plant operates on the electric eye, within the blanket's stability, and or until the high water limit switch is reached, in the clearwater storage.

If we can dim the lights, and have the slides now. I will go into more detail.

Slide No.

1. Aerial
   Castor is located in east central Alberta on Highway No. 12 about 100 miles east of Red Deer. This Aerial will give you an idea of what it looks like.

   Water reservoir (114 million gals.). Intake, Plant (old and new) Storage, Distribution system, Collection System, Sewage station, Lagoon (4 anaerobic, 1 aerobic, 1 storage).

2. Control Panel
   2-30 H.P. Pumps (20711.6 m) A.M. - P.M. Clock Aeration at reservoir intake. Water often all winter, 1/3 H.P. pump and perforated poly pipe under water (No. H^2S). Plant start changed to only when water coming in.

   Pressure switch, 3 power sources.
   Line heater adds 4° (8° - 9°)
   Chemical feed points charged 1 Alum (30-90 mg/l) just after heater. 2 Activator (8102) 7 mg/L just after aerator. 3 Polymer at rapid mix (1041) 5 mg/L.
   Desludge 20 sec. every 15 min.
   Clearwell 2-25 H.P. - 400 G.P.M. 80 P.S.I. pumps
   1 Natural Gas - electric pump
   Low level red and green pilots in mix tanks also
   1,2,3 (top) and 1,2,3 (bottom) marks inside

3. Probe and Relay Box
   Light source case, adjustment screw, and pilot monitor wash optic ends when pilot dims.

   Optic tubes, end adjustment lock nuts, Relay box, timer in main control panel (set at 15 min.)

4. Probemount height adjustment thumb screw

5. Probe in clear water and blanket below

6. Close up. Possible screen protector, for minnows
7. Blanket engaging probe
8. Ultimate ski experience
9 Lunch on a glacier

WATER POINTS - TYPES AVAILABLE

Peter Fraser,
Gladwall Engineering Services Ltd.
Edmonton

How many people here, have somewhere in their water system, a place for dispensing that water?

That is what we at Gladwall refer to as a "Water Point", that is; some way of dispensing water to your municipal crews, industrial users, water hauling contractors or the general public. Mr. Smith on the corner, who wants five gallons of your good clean treated water for his gold fish or the fellows at Dome Petroleum who use 5,000 gallons a day on their drilling rig and in their camp.

There are several different reasons or requirements for dispensing water and that is why there are many different ways of doing it. Every way from the simple outside hose bib to the complex batch metering systems. Today I hope to touch on the more common systems available and the pro's and con's of each.

Everyone knows the problems associated with an outside hose bib. Vandalism being number one. What kid out at Hallwoween wouldn't just love to turn on the water at the water plant and let it run all night, or maybe all weekend. Monday morning you wonder why your reservoir level is down or you wonder what happened to all that back fill you just put against the south wall. Freezing is another problem that I don't think I have to get into.

A hose bib is great for watering your own back lawn, but not for dispensing your precious municipal water. Especially to the fellow from Dome who's looking at double time and a half to fill his tanker.

Trying to overcome the problems of vandalism and short supply, a few people have gone to the rope pull valve. Simply a rope, with some pulleys, connected to a spring loaded valve inside the water plant building. We now have a greater supply of water for the tank truck driver, but we still have major problems with this type of system. The guys hauling water really don't want to spend 15 minutes pulling hand on this rope, every time they fill up. They usually concoct some ingenious method of tying off the rope so that they can stand around and have a smoke. If they can do it, so can the kids out at Halloween and you still have that problem. Also, the point at which you shut off the valve is when the tank is overflowing, so they let go of the rope and the valve slams shut. At this point, the 100 gallons a minute flowing through the pipe stops dead and the water hammer will usually blow apart something expensive inside the plant. Cheap and simple but still not the ideal system. Some ingenious water plant operators, much like everyone here today, have built their own automatic and semi-automatic systems. Using a push button, or spring loaded key switch connected to a solenoid operated valve you can put together a simple operational system. But the push button is open to vandalism, water hammer can still be a problem and the key switch is of no use to Mr. Smith and his gold fish. These systems can be made more sophisticated using time clocks, auto-reset timers and the like, and some of these problems can be overcome, depending on the ingenuity of the operator.

Now we come to the Cadillac of Water Points. The batch metering systems. Both Neptune and Rockwell, major water meter manufacturers, have batching systems designed for municipal water dispensing. Basically they utilize a coin switch, or other electrical initiator, integrated with a water meter with a pulsing or contacting head, a batch controller and multiple, usually 2, solenoid valves. The coin switch initiates the process by signalling the batch controller to open the solenoid valves. The water meter meters the water (what else would a water meter do) and signals the batch controller every so many gallons. The batch controller is preset for a certain gallonage per delivery and shuts off the solenoid valves once that end point is reached. Two solenoid valves are used to prevent water hammer. The larger main valve closes first with the smaller secondary valve remaining open for a short time. This allows the water flow to slow down instead of stopping dead and protects all your expensive hardware. This is a very simple explanation of a rather complex system. Now you say; "Here we have the ideal system!" It can be installed to be quite vandal proof with only the coin mechanism being accessible from outside. It can be adapted to varying water flows depending on your particular application. The system is adjustable so that the price of the water can rise coincidentally with the cost of treating it. The multiple solenoids eliminate the problem of water hammer.

But! Comparing back to the rope and the spring loaded valve; this system is neither cheap nor simple. First of all you have a lot of hardware involved and adjustment of the batch controller is not simple. Secondly, a system like this can set you back 7 - 10 thousand dollars.

Is anyone here familiar with the Neptune batching system? And how did it work?

We at Gladwall heard cries of help from operators, consulting engineers and contractors involved in water plant construction. The engineers want something that works. The contractor also wants a reliable system as well as something relatively simple and easy to install. And you, the operator, want all that, as well as something that doesn't cost an arm and a leg and that is easy to adjust and maintain.

Being the capitalistic bunch that we are, we set out to solve all the problems, keep the engineers, contractors and operators happy, and hopefully sell a few systems as well. We muddled along the first little while, solving a few problems at a time and finally came up with the Gladwall Water Point. It is a system that keeps the problems of vandalism, simplicity, adjustability and water hammer in mind but doesn't get bogged down with the complexity or expense of a lot of hardware.

First of all, we designed a heavy gauge, stainless steel enclosure that may be installed either through the wall of a building or outside on a remote post. The box is weather-proof with only the coin mechanism accessible from outside. The back of the enclosure is fully hinged and locked to provide access to the internal components and coin box. All the timing adjustments are easily set through this back opening. If it is installed through the wall, then all access is limited to the inside of the building.

Next we come up with a simple electronic timing control to eliminate the costly and complex batch metering controls. A small micro switch on the coin mechanism initiates a solid state timer that opens and closes a solenoid operated valve. This timer is fully adjustable from one second through several hours of timing. It is also adjustable as to the number of impulses from the coin switch it takes to initiate timing. Therefore, the controls can be set for 25¢ or $1.50 depending on your application. The timer will also accumulate the pulses, meaning that if you want to dispense 100 gallons for 25¢, a water hauling contractor can also purchase 2,000 gallons for $5.00 without having to restart the system every 100 gallons.

To eliminate the problem of water hammer and the necessity of multiple solenoid valves, we use a solenoid operated valve that is slow-closing. This valve is designed for irrigation applications and is not easily fouled with dirty water. We have also fitted the valve with a limit stop that allows you to throttle the valve down to a desired flow rate. This flow control combined with the adjustable timer, very easily give you the desired quantity of water you want to dispense for a certain amount of money. All adjustable. Simple - eh!

Another problem we ran into in the field, is freezing of your outside line. As an easy solution, we provide a small normally open solenoid valve to be installed at the low point inside the building. As the system dispenses water the solenoid is energized and the valve closed. When the system shuts off, the valve opens allowing the outside line to drain back into the building and eliminate any freezing problems.

Also included in the control package are two nice little extras. Mounted on the front of the enclosure is an on/off switch. This switch will shut down the control circuit, thereby shutting off the water. The timing circuit, however, will continue to time out. This allows someone to fill a number of small containers without wasting a lot of water and also allows for slight misjudgments on the capacity of your tank truck. I think we have all seen the big skating rinks that form when the tankers are constantly overflowing in January.

The second extra is what we call a coin-blocking coil. Mounted inside the coin mechanism this coil releases a small pin into the mechanism on power failure. The pin automatically rejects all coins, when there is no power to the system. There is nothing worse than filling a machine with all of your quarters and getting absolutely nothing for it.

In addition to coin operated systems, usually using quarters, we can also supply the system with a token mechanism. This allows you to sell tokens to water hauling contractors and industrial users and to set the system for large volumes of water per delivery. Some municipalities have combined the two systems, utilizing the coin-op for small quantities and the token-op for large volume users.

Most systems we have supplied also include a totalizing meter to keep track of the water being dispensed. The meter is also handy for setting the flow rate on the control valve. And now you will probably ask, "How much?" I have given you simple but now how about cheap. A complete system including; enclosure, timing control package, solenoid control valve, solenoid drain valve, moisture proof junction box and totalizing water meter will range from $3,000.00 to $4,500.00, depending on flow rate and pipe size required. Less than half of the batch metering system.

Not cheap enough you say!

We also have available a Key Lock System. This system utilizes a key-lock panel, similar to those used at bulk gasoline outlets. Each customer has their own key and key operated switch on the panel. The customer simply turns their key switch on until they fill their tank and then switches off again. Each key switch has its own counter which is connected to a pulsing meter on the dispensing water line. The counter keeps track of each customer's purchases which can then be billed monthly from your office.

This system is ideal for areas where there are a large number of high volume users. The Key-Lock Panel can be modified to whatever number of stations you require. A small system can be had for approximately $2,500.00 with larger units rising only slightly in cost as you require just one meter with only the number of Key Stations increasing.

- Right now I would like to field any questions you may have regarding water dispensing Water Points.

- Demonstrate the unit.

- Thank you for your time and attention and I hope that I have made my point .....WATER POINT.. that is.

PRE-INSULATED PIPE-OVERVIEW

Gregg Gaylard, Western Sales Manager
Urecon Insulation Ltd.,
Calmar

As the title indicates, the purpose of this presentation is to give only an overview of insulated pipe. When we decided to present a talk on this subject, we had in mind that it would be a good opportunity to transmit a little information to those people who do not regulary have use for insulated pipe, but, who from time to time may experience freeze-up problems and then have to investigate the best approach they can take to rectify the problem.

In the course of the investigation, they will either contact their engineering consultants or may end up talking directly with us (or a competitor) for advice. At that point, we try to give the person any information and guidance we can concerning solutions to the problem at hand, including, if required, computer print-outs pertinent to the problem.

It takes considerable amount of time on a one-on-one basis with the person to assure him or her that the information they are being given is not just a sales pitch and that if they use insulated pipe, the problem will in fact be solved, or that it is at least one possible solution to their problem, if done correctly.

Presenting this paper then allows us a shot at pre-exposure to a larger group rather than one at a time.

To those of you who do already have experience with or knowledge of insulated pipe, possibly something we say or show you will be new to you. There are some in the room from whom we also obtain information which we may incorporate into our product line or system by way of improvements.

Over the past 15 years we have, as have our competitors, I'm sure, been innovators of new and better methods to use and incorporate into the insulated pipe systems, but we have also pirated ideas and improvements from people in the field and used them whenever they would improve on the product and its performance, and especially, and possibly most importanly, to improve on ease of installation in the ditch.

Insulated pipe to prevent freezing is not new. The basic concept of insulation is as old as the hills, however, insulation put on by the old methods which was half sections of insulation attached to the pipe and a mastic or other waterproofing material put in the joints to water proof them, then perhaps wrapped with roofing felts for additional waterproofing, and, mechanical protection has worked in some instances for many years. In many cases though it has failed, and this usually due to water ingress thru the outer jacket into the insulation half shell joints, migrating along the pipe, essentially destroying the insulation value.

This is not meant as criticism or fault of these other insulations. They are perfectly good when used for their proper application, or adequately protected to perform under these conditions.

Urethane insulation which is presently used on most systems to insulate circular shapes in a monolithic and continuous manner, and urethane being a closed cellular material has the ability to better resist the ingress of moisture, although still not totally waterproof so it has a H.D.P.E. polyethylene outer wrap put over it, and that is pretty well the way most pre-insulated pipe is made today. You might argue for more exotic finishes under certain conditions but this usually results in higher costs, so for the present, at least, it's poly outer jacket for most applications and the systems using the polyethylene jackets are reliable and performing well.

Urethane is the most efficient of all insulation materials next to a vacuum, and combined with its versatility of applications is ideally suited to this particular use.

The insulation systems presently in use have evolved after considerable time, experience and thought, but their ultimate success is dependent very much on the people putting them in, so it is absolutely vital that they are made aware of the importance of their work particularly regarding attention to waterproofing of joints. It is no use spending money engineering a job, then buying expensive materials only to have them installed in a way that never gives the system a chance to perform as designed.

So stress the importance of their work to the people installing the materials.

ENERGY AND DOLLAR SAVINGS IN PLANT OPERATION

Stephen Tyler, Manager
Policy Analysis & Liaison
Energy Conservation Branch
Alberta Energy & Natural Resources

INTRODUCTION

Many of Alberta's industrial plants and commercial buildings were designed before energy costs were a concern. Energy was plentiful, readily available and cheap in Alberta, and the cost of energy was one of the less significant operating expenses of most businesses.

Today, rising energy costs are a major concern and energy conservation has become a critical component in ensuring that industries get full value for expensive energy dollars. In many instances, conservation could be the prime element in maintaining competitive viability.

So, How do you get Started

The first step is to identify where and how energy is being used and to detect wasteful practices which can be corrected. This can only be done successfully by undertaking an energy audit of your premises.

In booklet #2, How to Conduct an Energy Audit, in the Alberta Energy $avers for Business and Industry series, you will learn how to conduct your own energy audit and identify losses which can be corrected by maintenance or operational actions entailing little or no cost --- turning down thermostat settings after hours and shutting off ventilation and exhaust systems when they aren't needed, for example.

When a more detailed technical analysis of your energy consumption is required, there is a source of help available to identify energy wasters and point the way to cost-effective energy-saving measures. Consider asking for a visit by Alberta's Energy Bus -- a no-charge energy conservation awareness service offered by Alberta Energy and Natural Resources as part of the national ener$ave program for industry and commerce.

The purpose of the ener$ave program is to help owners and managers do two things: 1) reduce energy costs NOW and 2) develop energy management programs which will keep future energy consumption and costs down.

What's an Energy Bus?

Each of Alberta's Energy Bus vehicles is equipped with a computer and various monitoring devices needed for in-plant checks. Staffed by a team of engineers and technologists, the Energy Bus visits industrial, commercial and institutional buildings throughout the province. The team will inspect your plant, analyse your energy use, advise you of conservation measures you might take and estimate how much you would save. There is no obligation to do anything the audit team suggests. Participation by building owners and managers is voluntary and Energy Bus audits will only be conducted at their request.

The prime purpose of an Energy Bus audit is to make company management aware of the dollar savings that may be realized by improving the efficiency of energy use. The computer analysis points the way to dollar savings available, helps the company establish priorities for future actions and uses the specific company's actual energy costs, so that the correct investment decisions are made.

How do you get the Energy Bus to Call?

The ener$ave Energy Bus Audit is a free service offered by Alberta Energy and Natural Resources. If you are an owner or manager operating an industrial, commercial or institutional building in Alberta, take advantage of the free analysis of your facility's energy use and the expert advice offered by the audit team.

Requests for an audit by the Energy Bus should be addressed to:

Energy Conservation Branch
Alberta Energy and Natural Resources
2nd Floor, Highfield Place
10010 - 106 Street
Edmonton, Alberta
T5J 3L8
Telephone 427-5200

In preparation for an Energy Bus visit you'll be asked to provide us with your company's basic energy data. The information we need is listed in Energy Audit Data, booklet #4 in this series.

Compiling this information will identify all the points of energy use and is the essential starting point for your firm's reassessment of its energy consumtion.

The data required includes such information as:

Monthly summary of utility costs for 12 consecutive months.
Normal operating hours and occupancy of premises.
Building dimensions and materials of construction.
Window and door types.

Capacity of existing heating, cooling and ventilation equipment.
Type of lighting used.
Capacity of special equipment such as compressors and process heaters.

The actual bus visit is by appointment to minimize delays and save plant personnel time.

What Happens When the Energy Bus Visits

It normally takes the Energy Bus team no longer than two days to complete an energy audit and present the findings to the building's management. Adequate notice is given before the visit, for which no special preparations have to be made. The only exception to this is when members of the audit team will be required to wear safety equipment in the plant, such as hard hats, safety glasses or ear plugs.

The audit in no way disrupts the plant's operations. In fact, the audit team wants to be able to observe the plant under its normal working conditions.

Starting with an initial walk-through tour of the plant on the first day, the audit team inspects the building and takes a look at things such as insulation, the heating system, air leaks, caulking and weatherstripping. Experience has shown that a fresh look at a plant by an impartial observer often brings out many simple improvements that are missed by plant people because they are so close to the situation or are perhaps doing things a certain way through force of habit.

The team also holds discussions with key personnel, correlates the information from your completed Audit Data booklet with actual onsite conditions and takes measurements of energy use. In the process, the team might check ventilation fans, air flows, equipment use, employee movement patterns, heat recovery systems and lighting requirements. The list is virtually endless because buildings vary in design and structure, material and equipment contents, and use patterns.

On the second day, the audit team feeds all the data it has collected into the Energy Bus computer for analysis. The rear section of the Energy Bus is arranged to accommodate up to six people and it is here that the results of the audit are made known. Using the computer's video display and hard copy printer, the bus crew confer with the company's management and key personnel on areas of potential savings available, while the on-board computer provides fast analysis and evaluations of each situation.

Both the data collected and the computer analysis are treated as confidential. The printout itself is left with the building's management.

A typical Energy Bus computer analysis will include a heat loss analysis, ventilation checks and lighting calculations. Month-by-month electrical cost calculations are used to point out potential savings through improved power factor and load factor. Special calculations are done on systems that are unique.

Almost always, many no-cost energy-saving practices come to light during bus visits.

How can you Use Energy Audit Findings?

The Energy Bus audit team presents management with the hard facts on energy use and costs, and where savings can be made, it advises managment on how it can start its own energy management program. But it's up to management to decide what to do, and generally it can follow one or more of these three options:

Implement the no-cost procedures which will almost certainly have been noted during the audit.

Invest a small amount of money in new equipment and modifications which the energy audit shows will offer substantial savings.

Consider investing larger amounts of capital into higher-cost energy conservation projects. This is when the computer analysis demonstrates that large potential savings exist, but that they are dependent on capital expenditures which must be evaluated by management using the cost/benefit criteria specific to that company.

Energy Bus experience shows that every Energy Bus visit results in the identification of potential savings. Most plants can reduce their energy bills by 20 per cent. Occasionally the results are far more dramatic.

What the Energy Bus does is not new in itself. It's the way it does it that's different. The Energy Bus is a mobile and versatile service, and it's available throughout Alberta. It is this mobility, combined with sophisticated equipment and highly-trained engineers and technologists, which gives the Energy Bus its unique effectiveness.

Interested in having the Energy Bus audit your plant's energy use? Call the Energy Conservation Branch of Alberta Energy and Natural Resources to arrange a visit.

THE EDMONTON REGIONAL WASTEWATER TREATMENT PLANT

J.D. McIntyre, P. Eng.,
Alberta Utilities & Telecommunications

This paper presents a brief history of the Edmonton Regional Wastewater Treatment Plant, from the conception stage through to start-up and commissioning. The plant is a 20 mgd air activated sludge plant and has recently been completed at a cost of fifty-six million dollars.

In 1979, the Government of Alberta initiated a program whereby the province would implement multi-municipal water or sewer systems that were more cost-effective and/or environmentally acceptable than individual municipal water and sewage treatment facilities. At this time, the communities in the Edmonton area all had very high projections of growth and the possible expansion of many of the municipalities' local systems was imminent.

Rather than spend the dollars on expanding all of the local sewage treatment facilities and end up with several point source discharges, some of which would be upstream of Edmonton's drinking water supply, it was decided that a single regional plant would be built. The original concept had the plant providing sewage treatment services to Edmonton (portion of), Sherwood Park, St. Albert, Stony Plain, Spruce Grove, Gibbons, Leduc, Beaumont, Fort Saskatchewan, Morinville, the Municipal District of Sturgeon and the Counties of Leduc, Strathcona and Parkland. The connecting pipelines and sewage lift stations for some of these municipalities are now under construction. The treatment plant has been in the process of being commissioned.

The preliminary engineering for the regional plant was initiated in 1980. Consulting engineers for the project were Underwood McLellan Limited, Edmonton, Mr. Terry Higo, P. Eng., Project Manager. Gore and Storrie Limited, Toronto, were associated consultants.

A Technical Review Committee was established with representation from the surrounding municipalities and the province for input into the design and process selection.

Treatment Objectives

The standards that the plant was designed to meet are:

> The monthly arithmetic mean of the daily samples for both the standard 5-day Biochemical Oxygen Demand (B.O.D.) and the non-filterable residue shall not exceed 20 mg/L,
> The monthly arithmetic mean for total phosphorus shall not exceed 1.0 mg/L.

Although Alberta Environment has not required phosphorus removal to date on the North Saskatchewan River, the plant was built with the capability of removing phosphorus. Future environmental standards may require phosphorus removal.

The processess selected and the flow diagram is shown in Figure 1. The process selection was performed with the long-term operation and expansion capabilities taken into account. The intial layout of the site was planned so the future expansions and possible additional unit processes could be added at a minimum cost. The site plan is shown in Figure 2.

Preliminary Treatment

Sewage enters the plant through a 1500 mm influent line and flows are recorded with a 900 mm ϕ magnetic flow meter. Flow can then be diverted through one or both of the Degremont front cleaning climber screens. Parallel aerated grit tanks are spiral flow. Grit removal is by screw conveyor, to a pair of pumps, a pair of grit classifiers and a belt conveyor. Both the classified grit and screenings are taken by the belt conveyor to "lugger" containers for hauling to landfill. Screens are run on timers or alternately on high differential liquid levels.

Primary Treatment

Rectangular primary clarifiers were chosen for their better site utilization and ease of operation over circular clarifiers. Each of the two clarifiers are sized for 50 percent of the average daily flow. Overflow rates are 29 m^3/m^2/day at average flow and 72 m^3/m^2/day at peak flow. Travelling bridge clarifier mechanisms travel along the tanks on tracks. Primary sludge hoppers are located on one end of the tanks. Each hopper has its own pump for removal of the primary sludge. Pumps are air activated diaphragm type. This type of pump can be slowed to obtain a thicker sludge, whereas centrifugal pumps sometimes create "channelling" in the sludge hoppers allowing more liquid to be removed. The primary pumps are started on a time basis and allowed to continue running as long as the sludge density remains high. Operators can adjust the lower limit for sludge density.

Scum is collected with Dorr-Oliver chain and flight cross collectors. These are enclosed and have an outside source of applied heat to prevent freeze-up during cold weather. Both scum collectors deliver scum to a common collection tank from where it is pumped to the digestors, recirculated or mixed.

Secondary Treatment

Before design commenced a number of different secondary treatment alternatives were evaluated. These were narrowed down to the following which were evaluated in greater detail.

i) Conventional activated sludge (coarse bubble)
ii) Complete mix activated sludge (fine bubble)
iii) Complete mix activated sludge (surface aerators)
iv) Oxygen activated sludge
v) Rotating biological contactor

Alternative iii) (surface aerators) was found to be the least capital cost. The higher operating costs for this alternative however, led to the selection of alternative ii complete mix activated sludge (fine bubble).

This system was designed to provide completely mixed aeration cells. Two parallel tanks are rectangular in shape. Primary effluent and return activated sludge are introduced at one end of the tanks. Flow through the tanks takes about seven hours at average day flow.

The fine bubble aeration is provided by porous ceramic dome diffusers and a system of air piping in the tanks. Each aeration tank has some 6,300 individual diffusers and interconnecting piping attached to the bottom of the tank. These were tendered separately and installed by the general contractor.

Blowers

The blowers which supply air for the activated sludge system were chosen by the designers on a performance basis. Tenders for the 34,000 m^3/hour blowers were let and a number of quotations received. The manufacturers were required to quote a base price and a guaranteed efficiency. The costs of operation of the units for 25 years were then taken into account by using the "present worth" of all future operational costs. Some of the blowers had low cost and low efficiency. Their total "present worth" cost was high. Some of the equipment had low efficiency at partly loaded conditions. An economic evaluation using the present worth analysis was conducted on all of the equipment using a project range of operating conditions and interest/inflation rates. This resulted in the selection of two Cord Turbo blowers for some $996,000. These blowers were chosen for a number of reasons, the two main reasons being:

- turn-down capability
- lower "present-worth" (operation plus capital costs)

Final Clarifiers

Four circular clarifiers, 38 metres in diameter, provide final clarification. These incorporate portions of a design put forward by John R. Stukenberg in his paper Activated Sludge Clarifier Design Improvements, presented to the WPCF in 1981.

The three main features of the design presented by Mr. Stukenberg which were incorporated are as follows:

1. The lack of rapid sludge collectors and incorporation of standard sludge scrapers.

2. The positive scum skimming device.

3. The deflector plate below the effluent launders.

Overflow rates at average daily flow are 20 m^3/m^2d. The return activated sludge pumps are screw type and each have a capacity of 68 megalitres per day.

The return activated sludge is introduced at several points along the end of the aeration tanks, at the same location as the primary effluent. No provision has been made for introduction of the activated sludge at any other location in the aeration tanks.

The waste activated sludge is pumped to the primary tanks for "source thickening". This practice causes a reduction in usable primary tank capacity and a less settleable primary sludge. However, the designers had determined through economic evaluation, that "source thickening" is less expensive than building separate waste activated sludge thickeners at this time.

Sludge Treatment

Two anaerobic sludge digesters, 33 metres in diameter, were constructed. The digesters are designed to be run in primary and secondary modes. Sludge mixing is by draft tube (confined gas lifter) and pumping through various suction and discharge locations in the digester. Sludge heat exchangers heat the sludge to 35°C in the primary digester. The secondary digester is unheated. Provision has been made to convert the secondary digester to the primary mode, through the addition of a draft tube and some external piping and valves.

The methane gas collected from the digesters is either compressed and pumped through the draft tube for further mixing or is burned in the boilers. Gas produced in excess of that required for the boilers is flared.

The sludge disposal method is currently under review. Disposal will likely be to sludge lagoons with eventual hauling to farmland and land spreading. Further discussions will be held with the City of Edmonton on possible joint usage of their nearby sludge lagoons and their sludge handling facilities.

Phosphorus Removal

Removal of phosphorus by chemical precipitation at the regional plant is possible. Three chemical storage tanks have been constructed near the aeration tanks beside the main tunnel each with 80 cubic metres capacity. These are designed to use either liquid alum or liquid iron salts as a settling agent for the phosphorus removal.

Provision for addition of the liquid alum has been made at the grit tanks, primary effluent channel, aeration tanks, and mixed liquor channels.

Phosphorus removal by chemical precipitation has a high cost associated with chemical purchases and a substantial portion of the total operating budget is used for these chemical purchases.

Monitoring and Control System

Three operating philosophies for the monitoring and control system were examined initially. These were:

- Local control with central monitoring
- Single control and monitoring
- Central supervisory control and monitoring

The mode selected was central monitoring with remote supervisory and local control. The system which has been built is more flexible than originally envisaged and several possibilities exist for operation interface and control, dependent on the philosophy selected by the operational authority.

Operators can control all of the processes from the central control room. Colored cathode ray tubes (C.R.T.) show the process schematics. As any piece of equipment starts or stops, the screen automatically changes to show the new configuration. This interactive capability makes complete monitoring of the processes possible. Alarm printers operate independently of the screens and controls. A totally separate "hardwired" alarm board will operate if the system is non-functional.

Four local operating centres can be fully operational without the central system should it be out of service. The system also logs all variables. A historical trend of variables can be stored on magnetic tape for review at some future date.

System Start-up

The Regional Commission which will run the facility has not yet been formed. It was decided that the facility should be tested during the warranty period to obtain the benefits of the warranties and to protect the plant from the extreme temperatures. At the present time, Underwood McLellan Ltd. has been contracted to start-up and commission the plant. The number of start-up problems have been reduced due to having the same firm in charge of construction and commissioning.

Sewage was first turned into the plant from Sherwood Park, population 30,000, on November 13, 1984. At this time, there was up to 1 foot of ice on the clarifiers. Precautions were taken to avoid having the mechanisms lift when the tanks were filled and became damaged.

Presently the plant is running at about 10 percent capacity. Some of the problems encountered during start-up have been:

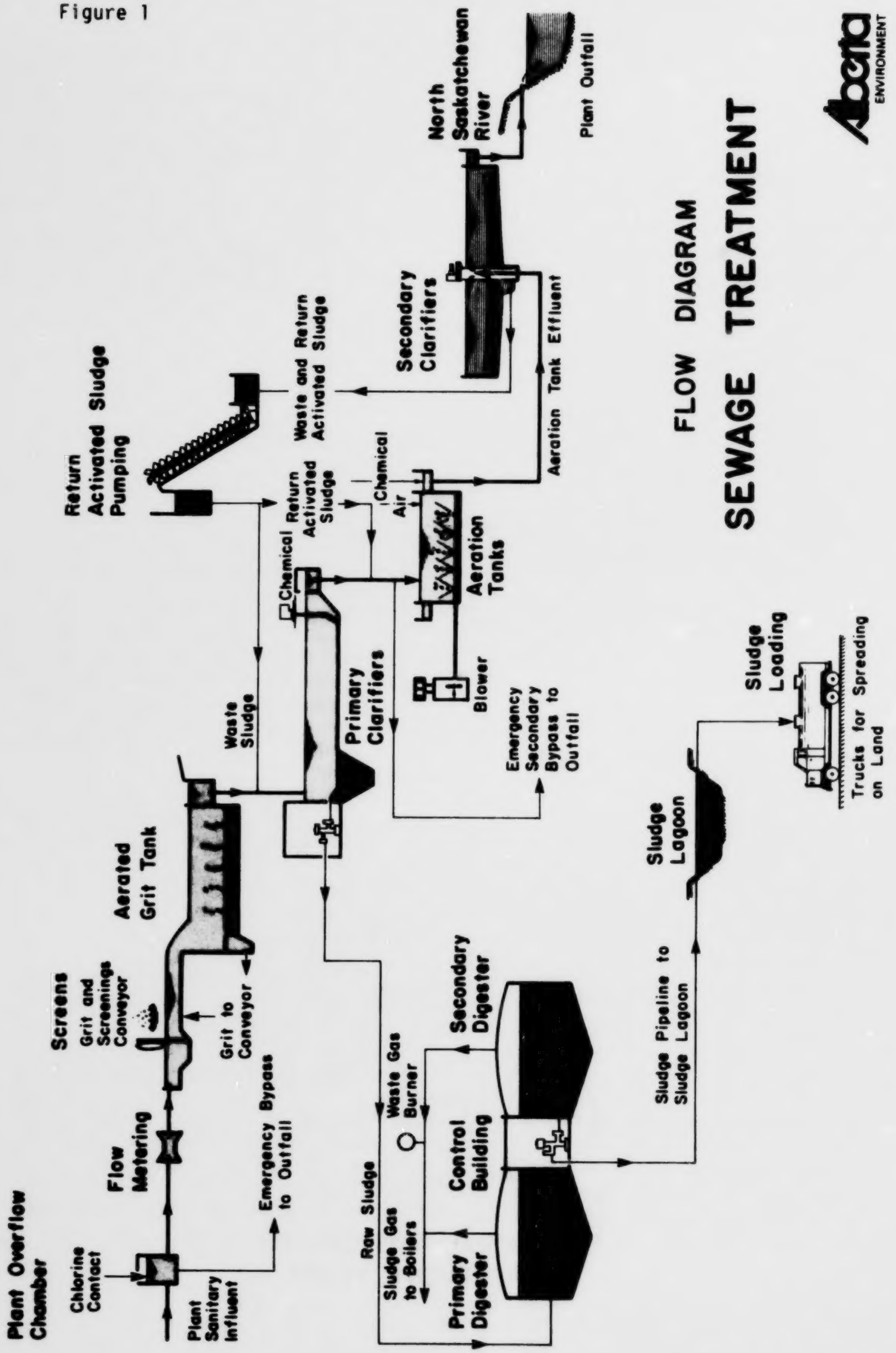
- One high speed Cord Turbo blower failed on testing. The impellor fractured and caused about $100,000 damage to the internal parts of the blower. Blower had to be removed and shipped to Denmark for repairs.

- Secondary clarifier scum skimmer mechanisms.
  - Failed to return to upright position - counterweights ran into scum pipe and bridge on subsequent revolution

  - Initially skimmer mechanisms caused large deflection of scraper arms when ducking under scum pipe. Underwater wheels were installed to limit deflection.

- Travelling bridge primary clarifiers initially would not lift scraper arm into maintenance position. Pulleys installed with 2-part line for additional pull solved this problem.

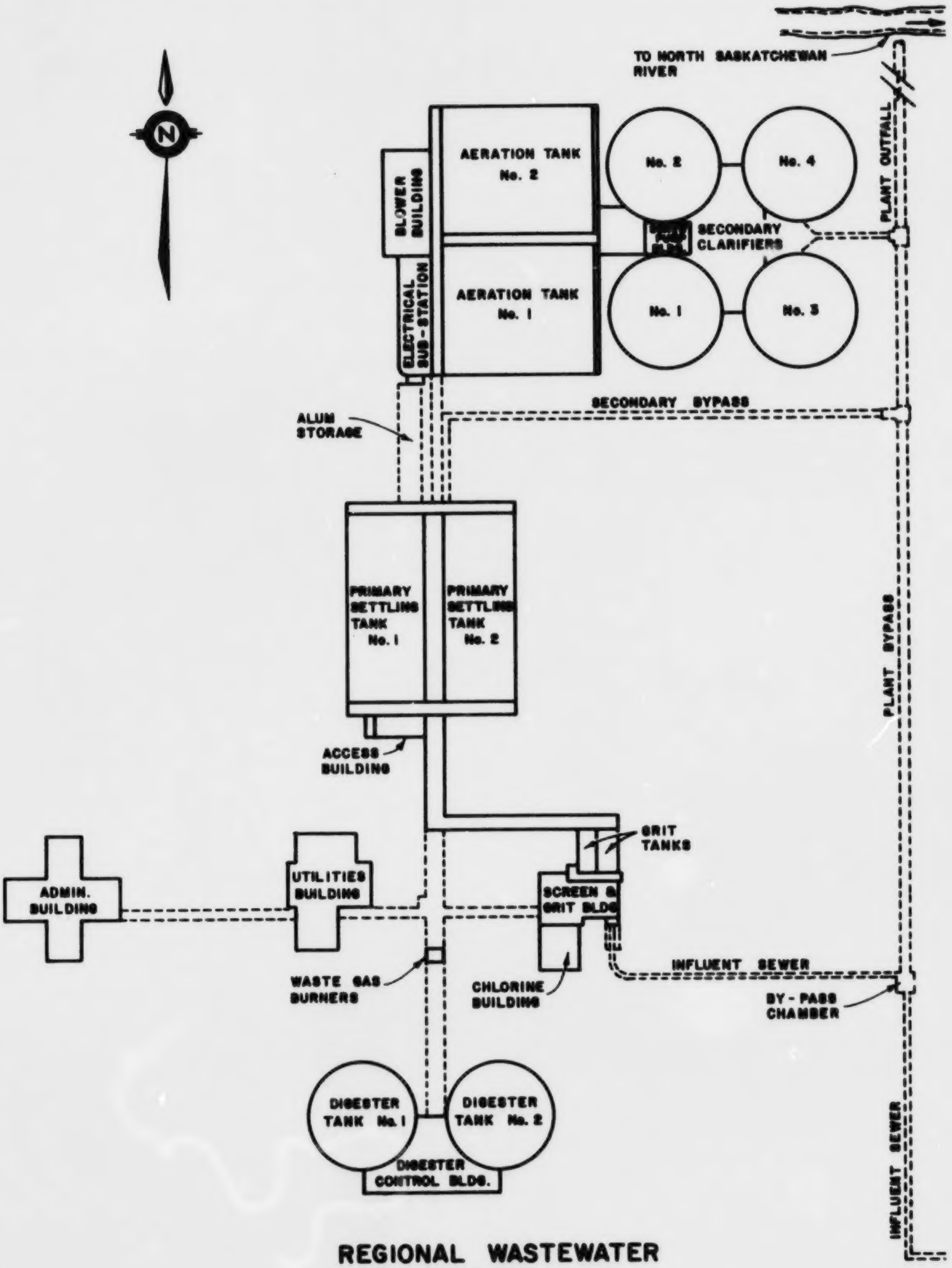
Figure 1


Plant Overflow Chamber
Chlorine Contact
Plant Sanitary Influent
Emergency Bypass to Outfall
Flow Metering
Screens
Grit and Screenings Conveyor
Grit to Conveyor
Aerated Grit Tank
Waste Sludge
Primary Clarifiers
Chemical
Return Activated Sludge Pumping
Return Activated Sludge
Chemical
Air
Aeration Tanks
Blower
Emergency Secondary Bypass to Outfall
Waste and Return Activated Sludge
Aeration Tank Effluent
Secondary Clarifiers
North Saskatchewan River
Plant Outfall
Raw Sludge
Sludge Gas to Boilers
Waste Gas Burner
Primary Digester
Control Building
Secondary Digester
Sludge Pipeline to Sludge Lagoon
Sludge Lagoon
Sludge Loading
Trucks for Spreading on Land
Alberta ENVIRONMENT

FLOW DIAGRAM

SEWAGE TREATMENT

Figure 2


N
TO NORTH SASKATCHEWAN RIVER
PLANT OUTFALL
AERATION TANK No. 2
AERATION TANK No. 1
BLOWER BUILDING
ELECTRICAL SUB-STATION
No. 2
No. 4
No. 1
No. 3
SECONDARY CLARIFIERS
SECONDARY BYPASS
ALUM STORAGE
PRIMARY SETTLING TANK No. 1
PRIMARY SETTLING TANK No. 2
PLANT BYPASS
ACCESS BUILDING
GRIT TANKS
ADMIN. BUILDING
UTILITIES BUILDING
SCREEN & GRIT BLDG
INFLUENT SEWER
WASTE GAS BURNERS
CHLORINE BUILDING
BY-PASS CHAMBER
DIGESTER TANK No. 1
DIGESTER TANK No. 2
DIGESTER CONTROL BLDG.
INFLUENT SEWER

REGIONAL WASTEWATER
TREATMENT PLANT

TURBINE WATER METERS VS COMPOUND WATER METERS
- WHICH ONES TO USE -

T.R. Schultz, Western Area Supervisor,
Municipal & Utility Division,
Rockwell International of Canada Ltd.

One thing is obvious when it comes to deciding whether you should use a compound water meter or a Turbo-Meter--there are a lot of factors to be considered. And, these factors vary from state to state, city to city.

Both types of meters were devised to meet certain uses. By understanding both the design and capabilities built into compounds and Turbo-Meters, you will be in a better position to choose the right big meter for the right measuring application.

It is difficult for Rockwell, as a meter manufacturer, to establish specific recommendations on a nationwide basis because of the variety of local situations possible. We do feel, however, there are certain guidelines which can aid the water utility in selecting the proper type meter.

On new installations, compound meters generally should be used wherever people are living. These meters are designed for applications where the majority of the flow is rather low, some intermittent and only an occasional high flow. Compound meters, with their individual measuring chambers, accurately measure from a fraction of a gallon up to the normal maximum capacity of the pipeline. Very small flows from faulty plumbing and individual faucet flows can be accurately measured.

Turbo-Meters, which also have a very wide flow range, should be used where the minimum flows are a couple of gallons per minute and the majority of the flows are moderate to high. They should be installed for work or pleasure purposes or where water is used in processing. Where people congregate, the instantaneous demand from restrooms, cafeteria, maintenance and other areas is usually sufficient to be at least several gallons per minute; therefore, a Turbo-Meter can be used. In these situations, the water usage by night watchmen and other people in the off-hours is insignificant when compared to the bulk of the water consumed by normal activity.

There are Exceptions to the Rule

There are exceptions, however, to this general rule of using compound meters where people are living. We know from customer reports that Turbo-Meters perform very successfully in large apartment complexes. In buildings with 100 apartment units and larger, Rockwell's W-350 DR and W-1000 DR Turbo-Meters are frequently being installed. There are enough people using water at any one time to produce flow rates within the range of these meters. On the other hand, complexes with only 20 apartment units definitely require compound meters because of the low flow rates possible when only a few tenants use water during off-hours. The problem is the gray area between the small and large apartment units; the local utility must decide which type of meter to use after considering several other factors, which will be discussed later.

On existing installations, Turbo-Meters can replace compound meters if, upon examination, extensive wear is evident in the compound's turbine chamber. If a compound meter is properly sized for the application, the wear to both the positive displacement and turbine chambers should be about the same. If only the positive displacement chamber shows wear, the compound meter is oversized. Only a worn turbine chamber indicates the meter is operating above crossover the majority of the time and a compound meter is not required.

We also see in many areas throughout the country where water lines are oversized. The architect or building designer may put in a six-inch line, for example, where only a four-inch line is required. The architect (or whoever specifies the pipeline size) is not necessarily at fault because, in many cases, there is little up-to-date statistical data to support his decision as to the required size. He also must anticipate unusual demand patterns and future expansion. Considering the cost involved in either replacing an undersized line or installing additional lines, the increased cost of using six-inch versus four-inch pipe is not significant.

On the other side of the coin, however, the architect's fee is usually based on a percentage of the project cost; therefore, he logically may specify a larger line to both protect himself and obtain a higher fee. The water utility then puts in a six-inch compound so as to measure any flow through the line.

Smaller Meters on Oversized Pipe

More utilities now recognize many water service pipes are oversized and are installing water meters one size smaller than the pipes. This represents considerable cost savings to the utility, particularly if it, rather than the water customer, purchases the meters. W-160 DR (2 in.) Turbo-Meters frequently replace two-inch and three-inch compounds; W-350 DR (3 in.) replace three-inch and four-inch compounds, and W-1000 DR (4 in.) are replacing some six-inch compounds. Most six-inch compounds are being replaced with W-2000 DR Turbos especially where there is a history of frequent maintenance on the compound. The W-2000 size Turbo-Meters have such high flow capacity they are used on eight-inch distribution lines, where current, Venturi and other high flow meters have been used in the past.

When Turbo-Meters with smaller flanges than that of the pipeline are used, tapered concentric reducers are required on both sides of the meter.

Rockwell does not recommend reducing the line more than one pipe size because of the potential change in flow rate patterns sometime in the future. A six-inch line, for example, can frequently be reduced to use a W-1000 DR; a W-350 DR would be too small (intermittent maximum flow rate is 500 gpm). Except for special distribution situations, maximum flow rates through any size pipeline are usually on the order of 12 feet per second. Turbo-Meters, particularly in the larger sizes, can therefore handle the normal maximum flow through the next larger size pipe.

Water Cost is a Consideration

In addition to knowing the type of service which is to be metered, there are other factors which can influence the final decision of whether to use a compound or Turbo-Meter. The cost of the water is sometimes a consideration. I remember reading the annual report for a particular city in Texas. The report gave a detailed breakdown of the meters, pipe, revenues, etc. I recall the water rates in that city were among the lowest in the country.

In this city, as with other areas where water rates are low, the customer was using W-350 DR Turbo-Meters in place of many three-inch compound meters. The reasoning is that the W-350 DR is less expensive than a compound meter and at such low water rates, it would be many years before they could justify the price differential with a compound meter. (On the other hand in areas with high water rates, every flow must be measured and compound meters should predominate.)

Another factor, which is related to the initial cost of the meter, is whether the meter is intended for revenue or just for accountability purposes. For the latter, a Turbo-Meter usually is adequate.

Last, but by no means least, is maintenance of the meters. Rockwell is well aware of the increasing cost involved with field or in-line testing, and resultant maintenance of large meters. When the Rockwell Turbo-Meters were designed, this was an important consideration. Turbo-Meters are so constructed that the measuring chamber is a complete and separate assembly. A Turbo-Meter measuring chamber can be tested in one main case and then changed to another with full assurance the accuracy is still valid. This is not true with other types of meters where the measuring chamber is separate assembly from the register.

Because installations of compound meters in many older settings, did not provide flexibility for removing the meter to perform periodic maintenance, it is common for the compound's measuring chamber assemblies to be tested in the meter shop and then placed in the compound's main case still in the line. This is acceptable if the meter is then tested in-line. If, however, the measuring chambers are just replaced and no after-assembly accuracy test run, there can be no assurance the meter is operating properly.

Large Meters Should be Scheduled for Maintenance

Another aspect of large meters frequently overlooked by water utilities is scheduled preventative maintenance. When a small meter stops, the utility immediately repairs it. Large meters, on the other hand, seldom stop, but instead slowly become inaccurate over long periods of time. Even though they may be few in number, large meters represent considerable revenue to the utility.

AWWA suggests testing large meters on a periodic basis; these recommendations are frequently ignored. Testing and repairing of large meters on a planned basis is imperative to maintaining high accountability and revenue within the system. In most instances, the cost of repairing a large meter is recovered in only a few months because of the resultant increased revenue.

With larger turbine type meters, preventative maintenance is particularly important. Rockwell Turbo-Meters will record tremendous quantities of water very accurately as long as the meters see a full open flow of water. This sounds rather basic, but in the majority of meters returned to us for repair, we have traced down the cause of failure to a debris-laden or partially clogged strainer. Most large pipelines contain various types of foreign debris. Rockwell includes a strainer as part of the larger Turbo-Meter package for two reasons: (1) the strainer protects the rotor (turbine) from damage caused by foreign debris and (2) it minimizes the required run of straight pipe in front of the meter.

Because of the lower head loss through Turbo-Meters, higher than previously obtainable flow rates sometimes occur. Any debris in the pipeline will have a tendency to move during high flow usage. By examining the screen on a periodic basis, any debris trapped can be removed before it blocks the screen sufficiently to affect the Turbo-Meter's performance.

Meter Performance is Documented

There are many excellent examples of how Turbo-Meters have been used to replace other types of meters, and data collected indicates excellent performance on all of the sizes.

In St. Louis, a W-5500DR Turbo-Meter replaced a 16-in. compound (not Rockwell) which had to be repaired every six months; it took three days of the utility's time to repair the meter. Because of the high head loss with the compound meter, the customer had installed booster pumps and was actually sucking the water out of the main lines. Once the W-5500DR Turbo-Meter was installed, there was no further need for the booster pumps. To satisfy the utility's curiosity that the Turbo-Meter was operating properly, the measuring chamber was removed after 13 months' service (1.3 billion gallons) and retested. The accuracy test results were within 0.2 per cent of the original values.

A water utility in California had a manifold of five six-inch distribution meters. These meters were repaired on a monthly basis, one meter per month; every five months the manifold was completely rebuilt. One W-5500 DR Turbo-Meter replaced the entire manifold. When I visited the installation last year, the Turbo-Meter had been in service for over two years with no maintenance required.

A utility in Pennsylvania had two eight-inch current meters in parallel on a 16-in. line. They replaced these two meters with one W-5500 DR Turbo-Meter; the meter has recorded in excess of three billion gallons ($1 million in revenue) with no maintenance.

I could relate numerous other examples of this type of performance. The large Turbo-Meters are more frequently reported because of the tremendous quantities of water involved; but the smaller Turbos are having equal success.

Turbo-Meters have proven themselves to be the most accurate type of meter for measuring moderate and high flows for extended periods of time.

Turbos Increase Revenue

In California, a utility changed out five FM meters on a non-fire service application with Turbo-Meters. In all cases, the Turbo-Meters increased revenues from five to 30 per cent. On domestic services where Turbo-Meters replaced existing distribution meters, there was without exception, substantial increases in revenue and long term performance. We have received several unsolicited commendations from customers because the Turbo-Meters paid for themselves in only a few months just from increased revenues.

It is impossible for us to predict or generalize on the Turbo-Meter's long term performance capabilities. We do know that registration well in excess of one billion gallons in the larger size Turbo-Meters can be expected. In water systems which do not contain entrained solids (silt or sand) we recommend measuring chambers be examined annually for indication of any wear to the rotor bearings.

We also suggest that, as a preventative maintenance procedure, the Direct Reading (DR) Register be replaced whenever its odometer turns over. We compare the changeout of DR Registers to changing the oil periodically in your automobile. We do not know how long the register will last, but because of the volume of registration possible between reading periods, if the register would fail between meter readings, the lost revenue far exceeds the replacement cost of the register. Turbo-Meters are designed to permit easy removal of the register. As with Rockwell's domestic SR water meter, changing of the register does not affect the calibration of the meter.

Compounds are Required

Some utilities are going to Turbo-Meters exclusively and replacing all of their existing compound meters. I personally feel this is too drastic a step because there are applications in every water utility where compound meters are required. There are instances, however where compound meters are improperly applied. On distribution and other high-volume lines, Turbo-Meters have a definite advantage over compound meters in terms of overall accuracy, long-term performance and low-cost maintenance.

Several utilities have installed Turbo-Meters in tandem with compound meters to determine for themselves which is the better meter. Until such time as I have an opportunity to personally inspect such installations, test both meters and perform an in-depth evaluation of the service application, I cannot believe that Turbo-Meters will completely perform the same service as compound meters.

In one Midwestern city, for example, a three-inch turbine meter was installed in tandem with a three-inch compound meter at two different locations -- a small school and a department store. The turbine showed eight per cent less registration than the compound at the school, and 2.9 per cent less registration at the store.

Still, the above illustrations represent one city's test at particular locations. Other tests have been conducted that prove the registration of the turbine-type meters to be higher than similar compounds.

Both compound and Turbo-Meters are excellent measuring devices and both have many applications. Until the Rockwell Series "W" Turbo-Meters were developed, compound meters were the only type available in the two-inch and larger sizes which could measure wide flow ranges. Current meters have been available for many years, but their flow ranges are rather limited and they do not have adequate low-flow sensitivity. Large meter applications must now be more closely analyzed by the water utility so the proper type of meter is used. We feel that compound meters and Turbo-Meters should complement each other, not compete.

TRAINING - AN OPERATORS VIEW

Andy Maguire, Operator II
Edmonton Rossdale Water Treatment Plant

The talk I'm giving today is on an operational view point of training programs. Basically, how we at the City of Edmonton Water Treatment Plants went about deciding on the necessity of a program and implementing it. Hopefully, if anyone here is contemplating setting up a training program, some of our ideas and problems may be useful for you.

There are four water treatment plants in the City of Edmonton, servicing approximately 600,000 residents and outlying communities for a radius of about 80 km. Rossdale Plants 1, 2 and 3 serve warm water to the Southeast, North, Northeast and core of Edmonton while E.L. Smith, Plant #4 serves cold water to the Southwest and West of Edmonton during the winter months. During the summer, all four plants are integrated in the distribution system. The distribution system is computerized using Digital PDP 11/44 computers and numerous terminals throughout the plants. The terminals display the reservoirs around the city, showing capacities, pressures, flows and valving, firehall pressures as well as suburban customers' pressures, flow and temperatures. Rossdale Plant is also in constant communication with the water yard who handles repairs and complaints, the Fire Department and the Rossdale Generating Station. Our water supply is the quite irregular North Saskatchewan River, containing at times high turbidity, colour, glacial silt and run off from the City. We have Class IV plants using coagulation, sedimentation, lime softening, chlorination, filtration and fluoridation in our treatment process. Our new processes include chlorine dioxide disinfection and experimentation with ozone. The combined plants production is a total of approximately 550 MLD.

Water and waste treatment is a complex, technical field. Until recently, most of the available training in Edmonton has been staff training staff, or on-the-job training, basic courses offered by the Alberta Environment, Pollution Control Division, and most recently, Westerra Institute of Technology. Unfortunately, past courses were not detailed enough, and with the staff-training-staff technique, too many irregularities were apparent in treatment procedures.

With our fields ever increasing with computerization, highly modern and technical equipment and an honest attempt at producing the highest quality product available, a definite need for a comprehensive training program was identified.

Previous training programs were tried on a hit and miss approach. Basic two and four hour training seminars were given in-plant by many chemical companies representing the water treatment field.

Though being useful in the basic understanding of the chemicals used, it lacked the hands-on practicality of the chemicals and actual reactions and properties of combining chemicals.

One of the benefits of these seminars were the detailed hand-outs of each chemical.

A second method tried was in-house personnel giving short talks. Management spoke in regards to different systems and new process procedures; Lab staff spoke on new methods and equipment for testing quality standards; and Maintenance spoke about new equipment proposed and in use. The in-house talks were beneficial but very little follow up was done and it was hard to bring theoretical experience into practical use.

The third and probably most used method of training was staff training staff. This is probably the easiest and most convenient way to train new personnel, but one of the hardest to control. A number of difficulties arise in this type of program such as:

- in the amount of time different people needed to train in some sections.
- some bad habits were passed along to new personnel.
- comprehension of procedures and testing were not fully understood in some cases by either the trainer or trainee and for a time due to high staff turnover.
- inexperienced people were attempting to teach new personnel.

Also, with the conversion from Imperial to metric, mathematics was found to be in need of upgrading.

A comprehensive organized training program was definitely needed.

Setting up a program was actually relatively easy. Combined experience was enlisted from operators, maintenance, lab staff and management. The services of Hovestad & Associates were used to compile this valuable information into two books containing three levels of operation.

Level one, is training for new operators, such as types of chemicals and their properties, hazards and safety procedures, loading/unloading, mixing and injection, setting feed rates, startup/shut down of chemical equipment, forms and records kept, etc.

The second level of training is for the more experienced operators. This course included such things as plant objectives, yard piping, reservoirs, distribution systems, computers, hydraulics, pumps, preventive maintenance, compressors and a detailed section of lab procedures and some chemistry.

The third and final level of training which at this time has not been implemented, is designed for shift foremen and assistants, supervisors and mid-management. Some of the items to be covered include special procedures for power failures, flooding, chemical spills and fires, river/source contamination, major equipment failures and even the possibilities of bomb and personnel threats.

With all the information now readily available, a slightly different concern occurred. Who shall teach the program. Should a professional teacher who is inexperienced in the field be hired or should it be handled by in plant staffing? Three young enthusiastic operators came forward volunteering to teach the course. Dale Bentz, Howard Preston and Karl Welz. Their patience and new found teaching abilities proved to be most valuable.

Due to shift rescheduling and a definite interest from operators, the training program was presented over two six-month periods with extraordinary results. High attendance, above average marks on quizzes and exams, an ability to understand plant process on a more responsible technical and professional level, progression to unrestricted licencing, are just a few examples of the positive response to the training program.

When setting up a training program, numerous things should be considered. Some additional ideas could be along the lines of emergency planning, record keeping/inventory control, safety, operational versatility, instrument control, microbiology, a glossary of terms, appendix, and the list goes on. The scope of the program should be tailored for all staff from utility workers to foremen.

A quote from the Manual of Instruction for Water Treatment Operators, "There are two main reasons for water treatment:

1. To provide water of safe, sanitary quality;
2. To provide an attractive water which is free from objectionable turbidity, colour, taste and odor.

With the operational training program now implemented at the City of Edmonton water treatment plants, I firmly believe that we are able to meet these goals with a high degree of pride. Training provides a purpose to our field.

Thank you,

PESTICIDES FOR MUNICIPAL OPERATORS

Jim McKinley, Technologist
Pesticide Chemicals Branch
Alberta Environment

Pesticide technology has come a great distance since the days when diesel oil and paris green were two of the mainstays in the battle against pests. Today's applicator has at his disposal, organic insecticides and herbicides that enable him to control pests to an extent that would have been considered impossible a generation ago.

However, these new chemicals still have one major drawback. Most of them are poisonous to man and animals. We have not as yet learned all of the tricks of the trade, for we have very few pesticides that are selectively toxic.

Pesticide are, by definition, designed to kill something, be it insects, weeds, fungi, rodents, etc. and therefore must be handled as poisons. However, despite their capacity to adversely affect human health there is a vast difference between toxicity and hazard where agricultural chemicals are concerned.

Even if a particular chemical is considered to be highly toxic this does not necessarily mean it is also highly hazardous. While on the other hand a chemical with a lower toxicity may present a high hazard to the user.

The toxicity of a chemical is normally given in terms of its LD_{50} value, this value is a measure of its ability to produce harmful effects to living organisms. LD_{50} refers to the lethal dose to 50% of a population of test animals and usually is an oral dose given to laboratory rats.

As an example the toxicity of the insecticide aldicarb is 0.8 mg/kg. This means that 50 out of 100 rats will be killed if each one is given 0.8 milligrams of albicarb for every kilogram of their body weight.

This appears to place albicarb among the most toxic pesticides we use, since by extrapolating this value to an average 75 kilogram man the lethal dose would be approximately 60 milligrams (0.8 x 75). A very small amount.

However, aldicarb is registered for use in Canada by the Federal Department of Agriculture under the trade name TEMIK®. It is widely used on chrysanthemums and poinsettias in greenhouses and for insect control on potatoes in the field. To date there have not been any reported cases of fatalities resulting from the use of TEMIK® in Canada.

At first glance it would appear that the users of aldicarb have been extremely lucky in avoiding being poisoned or they have been closely following all recommended safety procedures. Experience has shown that this is not the case.

The reason that the injury rate from using aldicarb is so low is because of the low hazard presented by the chemical.

The hazard that a chemical presents depends not only on its toxicity but in the circumstances under which it is used. Although aldicarb has a very high toxicity, it is formulated in a way that makes the application of it present a low hazard to the user.

Aldicarb is only available as 10% active ingredient granules to be applied to and incorporated in soil.

This is an example of a reduction of hazard by the manufacturer. However, the user of agricultural chemicals may also reduce the hazard of the pesticides he uses by observing the following procedures:

1. careful selection
2. proper handling
3. safe storage
4. safe disposal

Pesticide Selection

Choosing the correct pesticide is one of the most important steps taken in carrying out an effective pest control program. The pesticide chosen will not only have a bearing on the hazards the applicator subjects himself and the environment to but will also help in determining the effectiveness of the control program.

Before selecting a pesticide, the pest problem must be identified and a decision made as to whether pesticide use is worthwhile and if it makes economic sense. All too often pesticides are used even when the benefits obtained would not justify the cost of the chemicals and the application. In addition other methods of control are available i.e., proper sanitation. There is also a need for the applicator to have a greater understanding of the life histories and requirements of the pests he is attempting to control.

The pesticide selected should be one that will control the pest with minimum danger to other organisms and must legally be one that is currently registered with the Canada Department of the Agriculture under the Pest Control Products Act.

Handling and Mixing

Of the various work activities associated with pesticide use, the mixing and loading operation is considered the most hazardous. This is because any spills or splashes will generally contain a pesticide of a high concentration.

The following general safety instructions should be observed during the mixing and loading of pesticides:

1. Having selected the right pesticide for the job, read the label and carry out the necessary calculations. Obtain the proper equipment, including protective clothing, and have first aid equipment on hand.

2. Never work alone when handling hazardous pesticides.

3. Mix chemicals outside or in a well ventilated area. Carefully open containers. Never put any part of your body directly over the seal or pouring spout. The release of pressure may cause the liquid to blow out of the container. Open sacks with a knife rather than tearing them because dry formulations can billow up in your face. Always stand up-wind when loading or mixing pesticides.

4. Have clean measuring and transfer containers available. The measuring containers should be thoroughly cleaned after each use.

5. As the containers are emptied and drained, rinse each container three times. Drain each rinse into the spray tank before filling to final level (this also simplifies the disposal of the container).

6. Cleanup spills immediately. If pesticide is spilled on the skin wash it off with soap and water. Contaminated clothing should be changed as soon as possible and washed before using again.

7. Protective gloves should be washed before removing them

8. Persons mixing, handling or applying pesticides should never smoke, eat, or drink until they have washed thoroughly.

There are times when the chance of overexposure are increased and the applicator has to be extra careful.

1. New personnel - new and inexperienced people may be handling chemicals for the first time. Over exposures are more likely to occur among these people until they gain some training and experience.

2. A long hot spell in summer - many men become tired of using uncomfortable protective clothing and respirators during hot weather. Also people are more likely to become dehydrated during hot weather and may be susceptable to some chemicals.

3. Long periods of work - when the work load has been prolonged and heavy, persons who have had small repeated exposures which have not been severe enough to cause symptoms may be at the point where a small exposure may result in poisoning. Also equipment that was working well when may be faulty if not maintained properly.

Storage

The first thing that should be noted is that pesticides are poisons and have to be stored as such. Never, ever store pesticides in the home, to do so is just asking for trouble.

All pesticides should be stored in cool, dry, well ventilated buildings, that are inaccessible to children, animals and unauthorized persons. In addition all pesticides need to be stored under lock and key.

Pesticides should always be stored well away from food or feed. Herbicides of all types need to be stores separately from other pesticides. This is to prevent possible cross examination and errors in mixing.

Containers should be placed on racks or shelves to enable any sign of label or container deterioration to be noted at an early date.

It is a good idea to keep an inventory of all your pesticide materials. When purchasing new pesticides mark the date on the container so that you will know the date of purchase. This will help you in keeping track of your stock and will also let you know if a pesticide has become outdated.

Certain safety and other equipment should always be available in the storage area:

1. Washing facilities, soap and towels.
2. Fire extinguishers, sand buckets, etc.
3. Sawdust, sand or earth to absorb leakage.
4. Suitable empty containers, shovels, brooms, etc.
5. Protective clothing. Overalls, rubber or neoprene gloves/boots/apron and face shields. Also suitable respiratory protective equipment if more toxic compounds are stored.

No smoking, eating or drinking should be permitted in the pesticide storage area. All persons handling pesticides should read or be told of the proper warnings and safety precautions for the pesticides being stored.

Any spillage or leaking packages should be cleaned up immediately. Dispose of any leaking or damaged containers. When pesticides are being stored for any length of time, examine the container regularly to be certain that no leaks have occurred.

If a spill does occur you should isolate the affected area and keep all unauthorized persons out. It is important that the appropriate protective clothing is worn by all personnel who are dealing with the spill. The building should be ventilated before and while the cleanup procedures are being carried out.

If the spillage is on a hard surface such as concrete the appropriate decontamination procedures should be followed. If on earth or gravel the contaminated area should be dug up and disposed of. When using water to wash up pesticide spillage do not permit this water to enter the sanitary sewer or storm sewer.

If the spill is a liquid, use activated charcoal, absorptive clay, vermiculite, pet litter or sawdust to absorb the spill. Use enough to soak up most of the liquid. Then sweep or shovel it into a large drum. If the spill is a dust, granular, or powder then sweep or shovel it directly into a large drum.

Next cover the area with lime or bleach to neutralize the pesticide. Rinse the area with plenty of water to wash away any remaining poisons.

Once the spill has been cleaned up you should check your storage area over carefully to see if any other pesticides were contaminated by the spill. If they were, don't take a chance on using them --dispose of them too.

Contaminated Clothing

The clothing you wear when you apply chemical pesticides may pick up residues which can enter your body through the skin. The pesticide does not have to be spilled on the clothing -- contamination may be caused by drift.

Removing the contamination using home laundry procedures works well but some extra care is required,

Firstly, your work clothes should be laundered daily but don't wash contaminated clothing with other laundry.

Use hot water (160 F) and a full water level. Use the recommended amount of heavy duty phosphate-based detergent.

Thoroughly dry the clothes in an automatic dryer for 30 minutes.

Remove any leftover chemicals from the washing machine by running the machine through the complete cycle using detergent but no clothing.

Pesticide Disposal

There are basically two disposal problems; disposal of surplus pesticides and disposal of empty pesticide containers.

Surplus pesticides which are still in unopened containers may be accepted back by the manufacturer. If you have mixed too much pesticide for the job you may be able to make use of it in other areas or other individuals may be able to make use of it. The best method of disposal for a pesticide is to use it at recommended rates for its intended purpose. If these methods prove to be unworkable then you should contact the Pesticide Chemicals Branch of Alberta Environment for assistance. The use of municipal garbage facilities is not recommended for the disposal of surplus chemicals.

The disposal of pesticide containers poses a much larger problem. The key here is to properly prepare the container for disposal. The following steps should be taken to prepare containers for disposal:

1. Empty the container into the tank. Let it drain an extra 30 seconds.
2. Fill it one-fifth to one-fourth full of water.
3. Replace the closure and rotate the container. Upend the container so the rinse reaches all the side surfaces.
4. Drain the rinse water from the container into the tank. Let the container drain for 30 seconds after emptying.
5. Repeat steps 2 through 4 at least two more times for a total of three rinses.

Remember to empty each rinse solution into the tank.

Containers that have been properly rinsed are then acceptable for disposal. However, the containers should still be altered so that they cannot be used for any other purpose. This involves the crushing of metal containers and the breaking of glass containers.

TRIPLE RINSE

Rinsate	Run One	Run Two
First	6230 ppm	5850 ppm
Second	500 ppm	550 ppm
Third	110 ppm	120 ppm

Reduction of chemical contamination of containers by proper rinsing.

More efficient methods of container decontamination involves the use of caustic solutions to degrade the pesticide and form a non-toxic residue.

CONTAINER DECONTAMINATION
(ORGANOPHOSPHATES & CARBONATES)

Container size	Water	Detergent	Caustic Soda (Lye)
Less than 5 gal.	1 pint	1 tablespoon	1 oz.
5 gallon	2 quarts	2 tablespoons	1/2 cup
15 gallon	1 1/2 gallons	1/4 cup	1/2 lb.
30 gallon	3 gallons	1/2 cup	1 lb.
55 gallon	5 gallons	1 cup	2 lbs.

Fires Involving Pesticides

Fires in which pesticides are involved present a much greater hazard than a normal fire. When pesticides burn toxic vapours are given off which pose a hazard not only to fire fighters but to individuals and property located downwind from the fire. The best method of dealing with the fire hazard is to prevent its occurrence.

The first step is to contact your local fire department. They can assist you in designing a fire prevention plan and inspect your facilities for fire hazards. This procedure also makes the fire fighters aware of what would be involved should a fire occur.

The fireman has a difficult enough job without having to face toxic fumes about which he is unaware and unprepared for.

If a fire does occur and pesticides are involved then all material involved must be considered contaminated and be disposed of accordingly. This will involve the disposal of containers, building material and water used in fighting the fire. Proper disposal will require you obtain special permits and could prove to be very costly. It is therefore advisable to consider putting extra effort into fire prevention.

EMERGENCY CONTACT NUMBERS AND AGENCIES

Agency Contact Number

Government of Alberta Department of Environment	800-222-6514 (24 hours)
Federal Government Emergencies involving chemicals "This is a transportation emergency"	477-8339 (24 hours)
Transport Canada (dangerous goods)	(613)996-6666 (24 hours)
Information and Emergency Center (Ottawa) General Information	(613)992-4624

Container Collection Program

The safe disposal of "empty" pesticide containers has been a problem since the first pesticide was packaged. We have seen the problem increase as more and more chemicals are used each year. The standard instructions for disposal are to bury 18" deep well away from surface or ground water. However, these instructions are seldom followed and the majority of containers end up in local landfill sites. This has only made the situation worse as the small landfills were never designed to handle this type of waste.

The Department of Environment began to notice large numbers of containers showing up in environmentally sensitive areas and in the summer of 1979 began a clean up of these areas in Southern Alberta. This then led to the establishment of a container collection study in the summer of 1980 to gauge the co-operation and response of the farming community to a collection program and to determine the extent of the disposal problem in Alberta. The study was also designed to investigate acceptable forms of container disposal such as recycling and burial at approved landfill site. It was also aimed at determining the feasibility of a co-operative working relationship between provincial and local authorities to establish and promote a functional collection program. The collection study consisted of the establishment of a series of temporary collection sites which presented the farming community with a safety alternative to their present disposal methods. At the same time, the collection project encouraged container clean up of the environment, thus further minimizing public and environmental hazards.

The project extended across Alberta, covering a good portion of each region. A total of 122 collection depots were established and 80,473 pesticide containers were collected at these sites. In addition, 1244 containers were removed from sensitive or problem areas. The summer project revealed that the container disposal problem was evident across the province. It determined that the co-operation and response of the Alberta farming community was generally very good and highly dependent on-site location and program publicity. The project also determined that a working relationship between provincial and local authorities was not only feasible but very beneficial to the success of the program. The study determined that shredded, metal pesticide containers could be safely recycled at a foundry when furnaces were operating at normal temperatures.

The success of the 1980 study has led to the establishment of a permanent collection program. Funding is being made available to local municipalities for the construction of permanent collection sites and at the present time twenty sites are either completed or under construction. We expect to have seventy to seventy-five sites up in 1985. We have purposely kept the number of sites down because we do not wish to create more of a hazard than we have now by allowing uncontrolled sites in areas where they will not be visited on a regular basis.

A system of handling and recycling the metal herbicide containers has been worked out with a local steel foundry and extensive air monitoring at the plant has shown that any remaining residues are destroyed by the high temperatures of the steel furnaces.

The increasing use of plastic for container construction has created a problem for us in recycling, however the fact that the plastic containers drain better than the metal version does to some extent offset the lack of recyclability. We are continuing to collect and store the plastic while we search for a safe disposal or recycling method.

CULVERT CAPACITIES AND THE MAKING OF REINFORCED CONCRETE PIPE

M.T. Yakemchuk, P. Eng.,
Sales Manager, Pipe Division
Consolidated Concrete, Edmonton

Concrete pipe has been in use in North America since the mid 1800's. Since those early days, many changes have been made in manufacturing techniques. The industry is still taking advantage of improvements in technology.

The success of the concrete pipe industry has been due, in part, to:

- The use of locally available raw materials
- The location of production centers close to construction projects.
- The services, such as participation in this seminar, provided to engineers, contractors, and public officials.
- The quality and durability of its products.
- Its ability to accommodate the requirements of its customers.

Specifications

Concrete pipe is manufactured to specifications that are developed through a consensus of users, specifying agencies, manufacturers and people with a general interest in the industry and its products. These specifications cover the materials used in the manufacture of pipe, the tests required to ensure that the raw materials and the finished products meet the specifications, and the various strength classifications of the pipe.

The following are the American Society for Testing and Material specifications most often used to define concrete pipe and related products.

-C655	Reinforced concrete D-load culvert, storm drain, and sewer pipe (metric).
-ASTM C14	Concrete sewer, storm drain and culvert pipe/covers nonreinforced concrete pipe in three strength classes in sizes from 4 inch through 36 inch diameter.
-ASTM C76	Reinforced concrete culvert, storm drain and sewer pipe/covers reinforced concrete pipe in five strength classes in sizes from 12 inch through 144 inch diameter.
-ASTM C443	Joints for circular concrete sewer and culvert pipe with rubber gaskets. Covers joints where infiltration or exfiltration is a factor in the design including the design of joints and the requirements for rubber gaskets to be used for pipe conforming to ASTM C14 or C76.

-ASTM C478	Precast reinforced concrete manhole sections/covers manhole risers, bases, tops, and grade rings.
-ASTM C487	Determining physical properties of concrete pipe or tile. Covers procedures for testing pipe.

Materials

The raw materials used in the manufacture of precast concrete pipe, aggregates, cement, water and steel reinforcement are all produced locally and each is covered by ASTM standards relative to its properties and methods of testing.

Aggregates

Aggregates are granular materials of mineral composition such as sand, gravel, or crushed stone. They are classified as fine aggregates which are generally sands, and coarse aggregates which are generally larger than 1/4" in size. The maximum size coarse aggregate used in concrete pipe is 3/4 to 1 inch.

Aggregates are usually shipped to a pipe plant by truck and held in bins in sufficient quantity to enable continuous operation of the facility.

Cement

In Alberta, most concrete pipe is manufactured with sulphate resistant cement. Cement is delivered by truck and pumped into storage silos.

Reinforcement

The amount of reinforcing steel in pipe products is specified by ASTM standards or by special designs. The most common types of reinforcing are welded wire fabric, both plain and deformed and cold drawn wire.

Water

The addition of water to a mixture of cement and aggregates produces concrete. Through a chemical process called hydration, triggered by the addition of water, a gel is formed which generates heat and causes the concrete to harden. The water used in the manufacture of pipe must be free of impurities that might interfere with the hydration process. Almost any potable water may be used (no salt water).

Concrete Batching

The raw materials for the concrete are combined in proportions suitable for a particular product in a mixer. The aggregates are transferred from storage bins to the weighing bins and the mixer by a series of conveyor belts. Cement is usually gravity fed through a weighing bin to the mixer. Water is piped directly to the mixer.

Most people have some experience with concrete. Usually, they are familiar with "slump" concrete used for pouring sidewalks or foundations. Slump concrete has more water than is required for the hydration of the cement in the mix. This extra water is required to make the mix workable. The pipe manufacturing facilities use production methods that require a very dry or "no slump" concrete mix which appears much different from ready-mix concrete.

Reinforcement Fabrication

Reinforced concrete pipe includes cages of reinforcing. A cage is an assembled unit of reinforcing containing both longitudinal and circumferential wires. Cages are usually fabricated on cage machines or wire rollers.

Cage Machines

Cage machines use reels of cold drawn wire. Longitudinal wires are positioned according to pipe size and the circumferential wire is wrapped spirally around the longitudinals and automatically welded at each intersection with a longitudinal, a continuous cage is produced which is cut off at the appropriate length.

Wire Rollers

Wire Rollers use welded wire fabric in rolls or flat mats. The fabric is F-D through a series of rollers which roll it into a cage of the appropriate diameter. When the proper length of fabric has been formed, it is cut off and welded to form a cage.

Manufacturing Processes

Most pipe is manufactured bell or female end down and during manufacture and curing, is supported by a pallet which forms the bell. The reinforcing cage or cages are placed on the pallet and spacers are fastened to the cages to keep them properly positioned.

Dry Cast

The dry cast process has several variations but all use low frequency, high amplitude vibration to distribute and compact the concrete. With the dry cast process, both an inside form (core) and an outside form (mould or jacket) are used. Some techniques have vibrators mounted on the outside of the mould; others have vibrators inside the core. In some machines, the mould is fastened to the floor and the pipe and the core are lifted out of the mould. In other machines, the core moves up and down and finally retracts below the machine and the pipe and mould are taken off the machine.

SAFETY FOR SEWER WORKERS ENGAGED IN MAINTENANCE, INVESTIGATION AND REHABILITATION

Steve Blonsky, Superintendent
Town of High Prairie

Good afternoon, ladies and gentlemen. I think the majority of the people know me here and you've already been introduced to the topic that I am going to be speaking on. It is on Safety of Sewer Workers and also on Maintenance of Sewer Systems in communities and towns, and possibly cities. I am not familiar with cities because I myself come from a small town.

I have had the opportunity to see good work done in our community and also we've had some problem areas in our community. The majority of this presentation this afternoon will be a slide tape presentation and I think it is a good presentation and I hope everybody is awake while they are watching it. It should be remembered that these are guidelines and may need to be improved or altered for specific equipment and facilities.

At this point I would like to mention that final approval for specific procedures is the responsible of the Occupational Health and Safety Division of the Department of Labour.

Pay particular attention to making the worksite safe and be aware of hazards for workers and the public.

As you have seen in this presentation, a number of the situations are really common sense and shouldn't really require conscious effort on our parts to make them safe. Too many times, we try to take a so-called short cut and run into problems.

We've seen a number of important points in this presentation, and as well, I'm sure there are a number of them which haven't been included. I'd like to make a few comments and recommendations from my own experience at this point.

In my past experience of operating a sewage collection system I've seen, if they are not maintained and scheduled proper maintenance, the cost involvement and the time that the system isn't working properly is quite costly. I've seen where we've had to go out one-two o;clock in the morning to rod a main sewage line which has been plugged up. Since we've gone to a scheduled system of operating our sewage collection system and by this I mean, cleaning the manholes, I know that when we mention cleaning the manholes, everybody turns their nose up, but it's a thing that has to be done, if you're working for a town community. I imagine, even in the cities, this is an essential part of making the system work and if you keep your manholes clean and pressure-flush your system maybe once every two years the problem areas may be a little more often, it will eliminate the downtime of the system and the times you will have to be called out of bed in the middle of the night to go rod a main sewer line. In my own experience over the last 2 1/2 years since we've gone into that system, I believe we've had one main plugged up and this was in the day time. We haven't been called out in the middle of the night for the last three years.

Doing as I mentioned, if you follow the system through, it avoids the overtime. It also avoids the customers' complaints which you yourself have to take and which also go higher up to the mayor, and then you get it from both ends. The system has a greater capacity and it is much easier to work with.

The last item that I can say of what we've been doing in our system is when we let out any sewer contracts to a contractor, it is built into our specs that before the final payment is given out to the contractor, we run a TV camera through to check the quality of work that is being done by the contractor. This, too, will eliminate future problems for you as a utility operator in making sure the utility works properly for you.

FLOW MEASUREMENT IN SEWAGE PUMPING STATIONS BY VOLUMETER

Elaine Conner,
Control & Metering Ltd., Calgary

Prelude

It is doubtful that another flowmeter can provide similar accuracy to measure and display total 24 hour flow through the pumping station. Even with this capability, Volumeter also measures and displays inflow rate and pumping rate, altogether, in one universal flowmeter.

It is not a matter whether Volumeter will "work" at a pumping station, the design theory and operating installations prove this. The only consideration is the accuracy it will provide. In pumping stations where the pumps are sized correctly, Volumeter typically provides ±1% of actual 24 hour total pumped flow.

This paper has been prepared by Volumetric Limited to assist in the understanding of the Volumeter as a flowmeter for sewage pumping stations.

Volumeter is a flowmeter for sewage pumping stations. It measures and displays (and provides output signals and alarms for) inflow rate, pumping rate and total flow pumped. The pumping station must operate its pumps on a start/stop basis (not variable speed drive).

An applicable pumping station has a series of inflow cycles followed by pumping cycles. The combination of an inflow cycle and subsequent pumping cycle we define as a "Volumeter Cycle". Volumeter operates based on these two cycle times. For most accurate flow measurement, the inflow cycle time should be longer than the pumping cycle time and there should be several Volumeter Cycles per day.

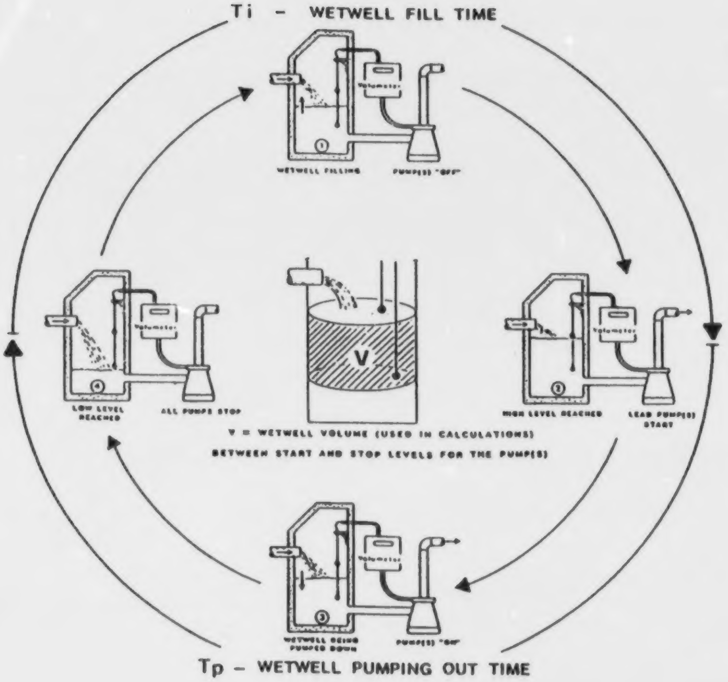
Volumeter is very simple. Its operation is as a dual timer and a special computer.

(1) It measures the time (Ti) required to fill the wetwell volume (fill cycle).

and

(2) It measures the time (Tp) required for the pump(s) to empty the wetwell volume (pumping cycle).

Volumeter Cycle


Ti - WETWELL FILL TIME
Volumeter
① WETWELL FILLING
PUMP(S) "OFF"
② HIGH LEVEL REACHED
LEAD PUMP(S) START
③ WETWELL BEING PUMPED DOWN
PUMP(S) "ON"
④ LOW LEVEL REACHED
ALL PUMPS STOP
V
V = WETWELL VOLUME (USED IN CALCULATIONS)
BETWEEN START AND STOP LEVELS FOR THE PUMP(S)
Tp - WETWELL PUMPING OUT TIME

FOR BEST RESULTS: $Ti > Tp$

Using these two time measurements and by using the wetwell volume (V) between the start and stop levels for the pump(s), Volumeter computes the following:

$$\text{Inflow Rate} = \frac{V}{Ti}$$

$$\text{and, Total flow Pumped} = V + \frac{V}{Ti} \times Tp$$

$$\text{and, pumping rate} = \frac{V + \frac{V}{Ti} \times Tp}{Tp}$$

These two flows and totalized flow are all measured and displayed in a compact wall mounted enclosure.

The input signals used to measure the time (Ti and Tp) come from the wetwell level controls used to start and stop the pump(s).

The wetwell volume (V), is measured or determined by the customer and entered into Volumeter's computer program via an integral keypad mounted on Volumeter.

The Volumeter measures both in imperial units or metric units.

An example of a flow calculation in Volumeter is as follows:

V (wetwell volume) = 1000 gallons (entered via keypad by operator)
Ti [time to fill the wetwell volume (V)] = 40 minutes
Tp [time for pumps to empty wetwell volume (V)] = 20 minutes
Inflow Rate = 1000 ÷ 40 = 25 gallons/minute
Total Flow pumped (for this Volumeter cycle)

$$= 1000 + \frac{1000}{40} \times 20$$

$$= 1500 \text{ gallons}$$

Pumping Flowrate = 1500 ÷ 20 = 75 gpm.

A more descriptive example is as follows:

Example

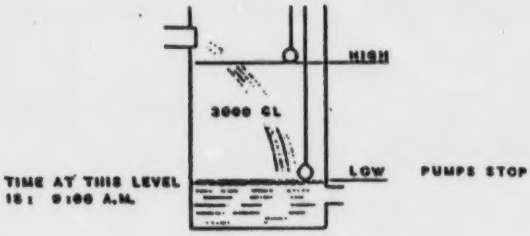
Data Available from Customer

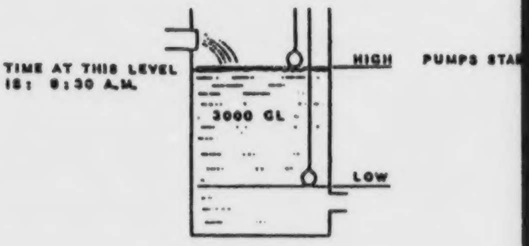
Volume of wetwell from pump stop (low level) to pump start (high level) is 3000 gallons.

How does the Volumeter calculate...

Pumping cycle just completed... Filling cycle now starts...

(a) Inflow rate:

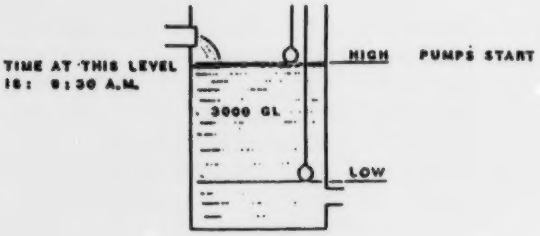

HIGH
3000 GL
LOW
PUMPS STOP
TIME AT THIS LEVEL
IS: 9:00 A.M.


TIME AT THIS LEVEL
IS: 9:30 A.M.
HIGH
PUMPS STA
3000 GL
LOW

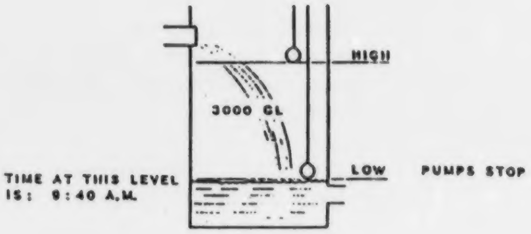
$$\text{Inflow rate} = \frac{3000 \text{ gallons}}{30 \text{ minutes}} = 100 \text{ gallons/minute}$$

(b) Pumped flow rate:

Filling cycle just completed...



Pumping cycle now starts...



Pumped flow rate = $\frac{3000}{10 \text{ minutes}}$ = 300 gallons/minutes
Plus average inflow rate calculated at filling cycle = 100 gallons/min.
Total pump flow rate is = 400 gallons/min,

(c) Total flow pumped during the Volumeter cycle in (a) and (b) as above is as follows:

Volume of wetwell	3000
Volume which came into wetwell during time pumps were on	1000 (10 min x 100 gals/min = 1000 gal)
	4000 gallons

If the next Volumeter cycle is the same as the one described above, then, the totalizer will show a total of 8000 gallons - 4000 gallons from the first cycle and 4000 gallons from the second cycle.

Volumeter is completely universal, the same model is used for all pumping stations regardless of wetwell volume, pumping rate, inflow rate, pipe size or other. Volumeter does not care about these so long as the wetwell volume can be measured and the time to fill the wetwell (Ti) and the time to pump out the wetwell (Tp) can be measured using the level controls. It does not matter if the inflow rate is large or small, or if there is one pump or there are several pumps all staged to come "on" at different levels.

Since most pumping station flowmeters are used for record or billing purposes to provide a daily, weekly or monthly total of flow pumped out of the pumping station, it is important to understand the parameters that effect this total pumped flow accuracy.

To review, for effective flow measurement using Volumeter, an applicable pumping station has a series of inflow cycles followed by pumping cycles. The combination of an inflow cycle and subsequent pumping cycle we define as a "Volumeter Cycle". Volumeter operates based on these two cycles. For most accurate flow measurement, the inflow cycle should be longer than the pumping cycle and there should be several Volumeter Cycles per day as follows:

Table 1
Volumeter Cycle Pattern - following diurnal flow

*1 1 Longest Desired time Duration based on Ratio in Column 4 (mins.)	2 Inflow Cycle Time (mins.)	3 Pumping Cycle Time (mins.)	4 Ratio of Inflow Cycle to Pumping Cycle Time	5 If this Cycle Occurred Constantly - the number of Volumeter Cycles per day would be	6 Normal Time when this cycle occurs
120	110	10	11:1	12	night flow
60	40	20	2:1	24	afternoon
20	10	10	1:1	72	7:00 a.m. - 9:00 a.m.

*1 - "Preferred" Volumeter Cycle Time

A mixture of these Volumeter Cycles occurs each day. Besides the normal daily diurnal flow pattern, these are affected by storm flows, unforeseen dumps and irregular pumped flows from other pumping stations into the station to be flow metered.

Column (1) Table 1, shows, as a rule of thumb, the longest desired Volumeter Cycle based on the Inflow Cycle time to Pumping Cycle time Ratio (column 4). It is to be noted: the lower this ratio, the shorter the desired Volumeter Cycle that is required to ensure best accuracy.

At this point, it is important to keep in mind three things. The Volumeter's main function is to measure and provide a read out representing the total daily, weekly or monthly flow. As a result, the instantaneous flow values are not as important as the accuracy of the total daily flow information.

The second point to keep in mind is that Volumeter measures inflow rate during the filling cycle and this inflow rate calculation is used to calculate the total flow pumped (and pumping rate) during each Volumeter Cycle. Hence, the filling cycle time should either be a long time duration compared to the pumping cycle time or there should be several (3 to 6) Volumeter Cycles per hour where the filling cycle time is the same as, or slightly longer than, the pumping cycle time.

The third point to keep in mind is that the inflow rate used to calculate the total flow pumped (and pumping rate) is measured during the preceding inflow cycle. As a result, the pumping cycle should be short compared to the inflow cycle.

Where the Volumeter Cycle Time is the same as or shorter than the times shown in Table 1 for various filling time to pumping time ratios, then Volumeter will produce a 24 hour total flow readout within ±1% of the actual 24 hour total flow. This is the Volumeter Accuracy Statement. Of course, it assumes that the level switches operate the pumps repeatedly at the same start and stop levels and that the volume calculation between these two levels is measured correctly and entered into Volumeter through the integral keypad correctly.

Whenever Volumeter is considered for a pumping station, the daily Volumeter Cycle Pattern for the particular pumping station is seldom known. Some rules of thumb assist in determining its applicability. It is applicable if one or more of the following situations exist.

(1) The pumps are "on" for 10 hours or less per day.
(2) The pumps cycle on/off at least 60 times per day.
(3) The max. pumping rate has been sized at least 2 x the maximum inflow rate.

This assumes that the lead pump starts at one discrete high wetwell level, that the lag pump(s) are staged at higher wetwell levels and that all pumps [lead pump and lag pump(s)] stop at one common level.

Even if the Volumeter Cycle Pattern does not follow the prescribed values as shown in Table 1, Volumeter still operates. It still measures flow. However, its 24 hour total flow accuracy may not be within ±1% guarantee. It may be outside this ±1% accuracy by the accumulative volume effect of all the "non preferred" Volumeter Cycles compared to the total volume pumped during the "preferred" Volumeter Cycles.

An example would be as follows
For a 24 hour period:
-total flow pumped during "preferred" Volumeter Cycles -
50,000 gal ±1%
-total flow pumped during "non preferred" Volumeter Cycles -
2,000 gal ±10%
-total flow pumped per day = 52,000 gallons ±700 gallons or ±1.3%

It is doubtful that another flowmeter could provide similar accuracy. As well, no other flowmeter for sewage pumping stations measures inflow rate, pumping rate and total flow pumped, altogether, in one universal flowmeter.

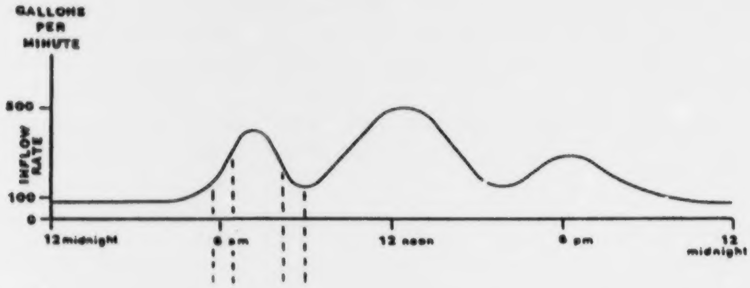
Volumeter uses a simple but ingeneous means of measuring flow. The read out information can be provided in the form of a typical chart recording using standard 4-20 mA signals for both inflow rate recording and pumping rate recording. These are available with Volumeter as a standard. Also as a standard is an RS232 output for a printer to provide all three flow readouts after each Volumeter Cycle. These three simultaneous printouts are inflow rate, pumping rate and total flow pumped.

Some examples of readouts compared to actual flow rates follows.

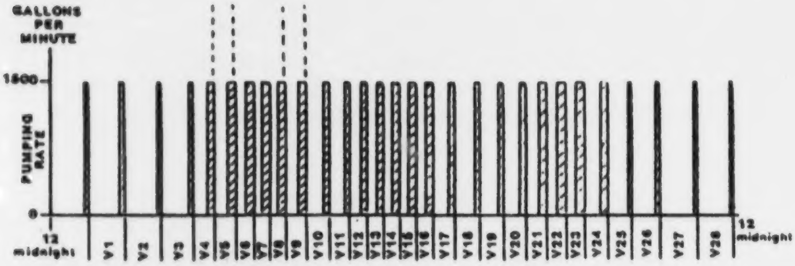
-sample flow rate record (as provided by a typical strip chart recorder for a single pump sewage pumping stations.

If two 4-20 mA strip chart recorders were used with Volumeter, Graph 1 and Graph 2 are typical charts that would be produced for a 24 hour period. The total pumped flow display would typically read.

Graph 1 - Inflow Rate to Pumping Station

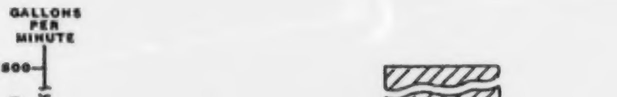


Graph 2 - Pumping Rate Out of Pumping Station

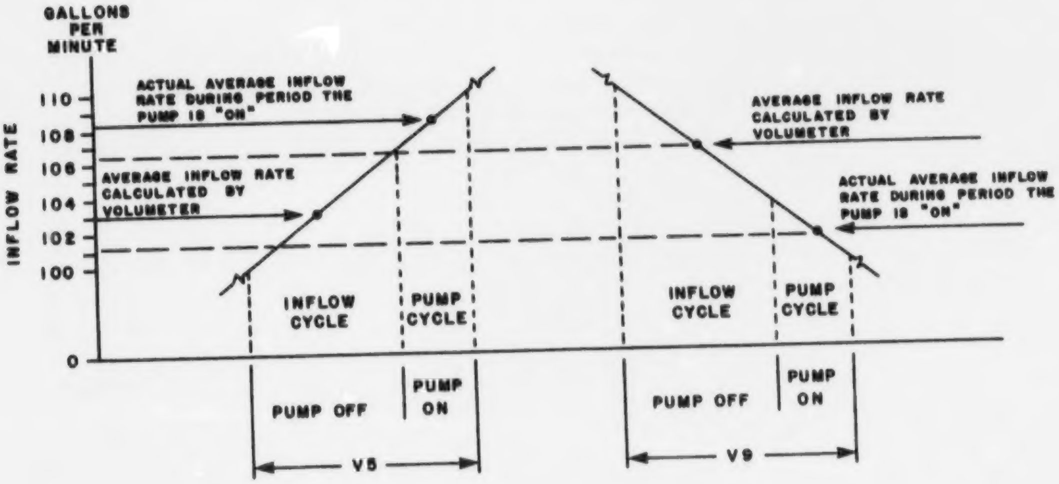


The Volumeter Cycles VI to V28 illustrates that a Volumeter Cycle includes an inflow cycle (zero pumping) and a pumping cycle (max. pumping)

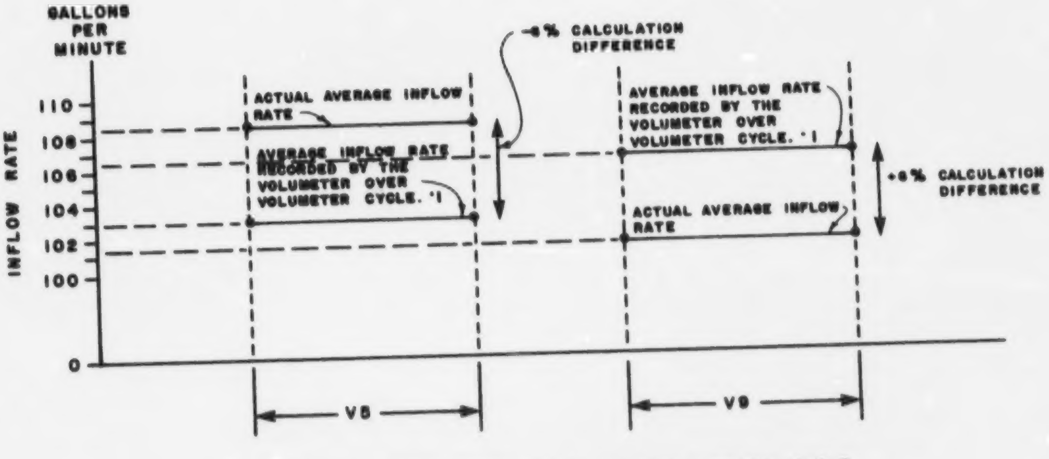
Graph 3 - Expanded Volumeter Cycle as Applied to a Strip Chart of Pumping Rate (Graph 2)



Graph 4 - Expanded Section of Inflow Rate Strip Chart of Actual Inflow Rate (Note - not as calculated by Volumeter)



Graph 5 - Comparison of Expanded Section of Actual Average Inflow Rate As Per Graph 4 Versus the Volumeter Inflow Rate Recorded

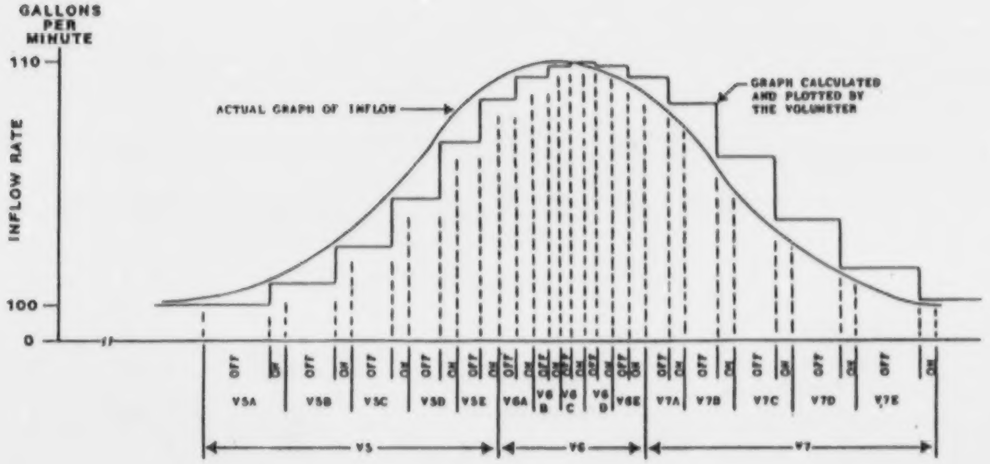


*1 - CALCULATION MADE DURING PREVIOUS WETWELL FILLING CYCLE.

Analysis - During periods of increasing inflow into the wetwell, Volumeter's calculated inflow rate is slightly lower than actual inflow rate. However, during periods of decreasing inflow rate, Volumeter's calculated inflow rate is slightly higher than the actual inflow rate.

Conclusion - As a result, if a 24 hour flow period follows normal diurnal inflow variations, for 24 hour totalized total pumped flow as calculated by Volumeter will accumulate as many "higher" and :lower" inflow rate calculations sufficient to reasonably cancel one another and provide a high (normally within ±1%) 24 hour total flow accuracy.

Graph 6 - Comparison of Actual to Volumeter Calculated of an Expanded Section of a Typical Increasing and Decreasing Inflow Rate



As shown above, the graph produced by Volumeter closely follows the actual inflow rate, however, it is offset (behind) by one Volumeter Cycle due to the nature of the Volumeter to calculate inflow rate during the previous Inflow Cycle (pump off), then the Volumeter calculated inflow rate produces graph components slightly lower and higher than the actual rate for each plotted segment representing each Volumeter Cycle.

Graph 7 - Typical Print out on Printer Using RS232 Output From Volumeter (standard)

```
  DATE        TIME       INFLOW RATE       OUTFLOW RATE    TOTAL PUMPED FLOW
83 02 11    06 59 57   INFL 102.700 g/m    974.300 g/m     0017147.062 K gals.
83 02 11    07 15 39   INFL 104.393 g/m    971.644 g/m     0018786.032 K gals.
```

The total pumped flow display would typically show:

0	0	0	1	8	7	8	6	8	3	2	gallons x 1,000

Calculations

In order to determine the Wetwell Volume compared to inflow rate, pumping rate and the maximum allowable pump starts per hour, the following calculations are prepared:

Inflow Rate = x gallons per minute
Pumping Rate = y gallons per minute
Wetwell Volume = V gallons

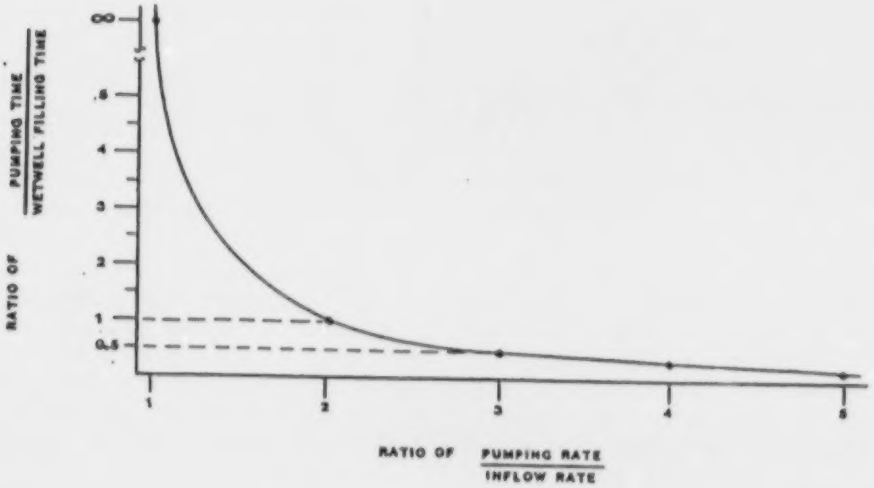
Therefore:

Time to fill the wetwell (Ti) = $V \div x$ minutes
Time to pump out the wetwell (Tp) = $V \div (y - x)$ minutes
Volumeter Cycle = $Ti + Tp = V \mathrm{E}\, x + V \div (y - x)$

$$= \frac{Vy}{x\,(y - x)} \text{ minutes}$$

Using the formula, if the maximum number of pump starts per hour is 6, the wetwell volume (V) (between the <u>lead</u> pump start level and <u>all</u> pumps stop level) should be sized 10 x maximum inflow rate (in gallon/min.) ot larger.

Using the above formula, the following table can be produced



The table shows that the wetwell filling time equals the pumping time when the pumping rate is 2 x inflow rate. As the pumping rate decreases, the pumping time increases. At pumping rate equalling 3 x inflow rate, the pumping cycle time is 1/2 the wetwell filling time.

For best results, the pumping rate should be at least 2 x inflow rate to ensure accurate flowmetering using Volumeter.

It is interesting to note that at 6 pump starts per hour, the Volumeter Cycle is 10 minutes and there would be 144 Volumeter Cycles per 24 hours.

THE USE OF OPERATIONS MANUALS IN OPERATOR TRAINING

Allan Yee, P. Eng.,
Operations Engineer,
Wastewater Treatment City of Edmonton

Introduction

A manual is a handbook of instructions. An operations manual is a handbook of instructions that details how to operate a particular process or facility.

This paper discusses some aspects of producing and maintaining an operations manual for a treatment facility and how that manual can be used in optimizing the operation of that facility. Although the example manual in question deals specifically with a sewage treatment plant, the majority of the points outlined can also be applied to other types of facilities in which processes of various sorts are carried out.

Production Approaches

Unless an operation is exceedingly simple and/or self evident, it is generally acknowledged that a manual of instructions and procedures would be a useful aid for personnel involved in carrying out the operation.

The problem of producing an operations manual is essentially one of technical communication. A piece of equipment or process exists. The proper information on how to operate the process or piece of equipment has to be obtained, organized, and written down and/or illustrated in such a manner that the end user can, by referring to the material provided, retrieve and use the information to, again properly operate the process or piece of equipment in question. The end goals are user comprehension and application. All other considerations become subservient to those goals.

In order to facilitate user comprehension and application, the information retrieval process must be as easy and painless as possible. The form of the information and its organization must therefore be aimed at being as complete, accurate, clear, concise, relevant, logical, and interesting as possible. More on these points later.

Given the foregoing then, there are a number of options for producing an operations manual. The user agency may hire someone, a consultant, say, to produce one for them. The consultant may be a communications specialist, a technical specialist, or a combination of the two. A communications specialist would be very good at analyzing, organizing and conveying information, but may not necessarily know anything about the information to be conveyed. Conversely, a technical specialist may thoroughly understand the information, but may not be very good at organizing and conveying it. Of the two, the communications specialist is to be preferred because, while the information comprehension and application by the user are the end goals, comprehension of the information by the conveyor is not necessarily a prerequisite to achieving those goals. In practice however, while the personnel who usually supply the documentation, such as the manufacturers or designers of a particular facility, are technically oriented, they also at the same time, have some varying degree of expertise in organizing the data into some sort of usable form.

Except for the case of a facility designer or manufacturer, the retention of a consultant to produce a manual will entail allocating operations personnel to give him the information he requires to produce it. The effort required to impart this information may be considerable. However, going the consultant route also offers the advantage of having an agent who can devote himself single-mindedly to the task of producing a manual without being diverted by day-to-day operational or administrative considerations connected with the facility.

A second approach to producing an operations manual is to handle it in-house. Assuming the availability of personnel on staff, one of them is assigned the task of coordinating the production and updating of the manual. The level of involvement on the part of the coordinator can vary from doing all of the tasks involved (including all the writing, drawing, possibly even the typing and reproduction) to merely arranging sections written by other on-staff personnel into a usable form.

There are a number of points to note about using the in-house approach. First of all, depending on his level of involvement, the coordinator might be required to devote a large portion of his time to producing the operations manual, thereby deterring him from spending time on his other duties and responsibilities. A facility is indeed fortunate if it has the manhours to devote to the task of producing its own operations manual. A second point to note however, is that the end result should be very user oriented because it will have been produced by the users themselves. Finally, in examining particular processes for documentation into a manual, questions are often raised which may result in changes being made to the process.

Edmonton Water and Sanitation has used both the consultant and the in-house approach in producing operations manuals for its treatment plants. The water treatment section retained a consultant (an information analyst) to produce an operations manual as part of an overall operator training package geared to their particular requirements. The wastewater treatment section, on the other hand, is producing an operations manual in-house using completely sectional resources. Both approaches are equally valid. The approach to be used by a particular facility will depend upon its specific needs, its resources (time, money and personnel) and its perceived most economical expenditure of these resources.

The Manual Production Process

Because of the author's orientation from the in-house approach to producing an operations manual, most of this section will deal with the production process as perceived from this particular vantage point.

First of all, a manual can document a process from a completely nuts and bolts perspective or it can contain varying amounts of narrative and explanatory material. A nuts and bolts approach deals strictly with the step by step instructions (open valve A, push button B, etc) required to operate a process or piece of equipment. No explanations are offered on how the process fits into a larger overall process scheme.

It is felt, however, that some explanatory material should be provided in an operations manual. While a rigidly nuts and bolts approach would make for a more concise manual, the provision of expository material will encourage a greater sense of initiative, responsibility, and hopefully, a higher morale amongst the operators assigned to the process. In other words, it is hoped that process benefits will occur from providing an operator with details on not only how he is to do a task, but also on why he is to do it.

There may be a question of how far to go in explaining the why or reason of carrying out a particular task. It is suggested that this is largely a matter of common sense. As an engineer the author can be rightly accused of holding what can be termed an engineering outlook. This outlook is largely concerned with process - how things work rather than why they work. As an example, the activated sludge process works because the microorganisms in the sludge can metabolize the majority of the organic materials in the sewage and then floc together into readily settleable masses. As to why they do so, that is now in the realm of the bioscientists and microbiologists. As long as the limitations to the process are known, and it can be made to work, the rest can be left to the scientists and philosophers to discuss.

At the Gold Bar Wastewater Treatment Plant, operator training consists of a combination of theory and hands-on-training. The on-the-job training is provided by the foreman and operators of the shift crew to which the trainee operator is assigned. The theory portion consists of classroom and homestudy training using material from a set of manuals issued by California State University of Sacramento and from another set issued by the Water Pollution Control Federation and Environment Canada. These manuals provide basic information on how various sewage treatment processes work and how to control them. The Gold Bar operators who have passed examinations on material covered in these manuals however, have a problem relating this information to how operations at the Gold Bar plant are conducted. It was therefore also felt that additional narrative material should be provided detailing how various sewage treatment processes are specifically applied at the Gold Bar facility. Given a plant or other facility for which an operators manual is to be produced, the first step might be to break down the process into a number of conveniently separated subdivisions. The documentation on these subdivisions can then form the various subsections of the operations manual. For ease of comprehension, the subdivisions can fall along process lines. For example, at the Gold Bar plant, the operation can be conveniently broken down into four basic subdivisions. These are the primary process, the digestion process, the secondary process, and control room operations. The Gold Bar operations manual is therefore also arranged along these lines, with additional manual parts added for a general introduction and lagoon operations.

The next step might be to further break down each process into a number of subprocesses based upon a number of factors such as the plant or facility training program, process layout, individual operator responsibilities, and personal author preference. It might, for instance, be deemed desirable to break down each process into a large number of subprocesses such that the material on one or more of these subprocesses can be easily covered in each operator training session. Conversely, dividing a process into too many subprocesses can inhibit the detailing of it. Certain procedures or parts of procedures may be common throughout an entire process and it might be deemed appropriate to cover the procedure, with all its variations, in just one portion of the manual. An example of this might be checks done on motors. For all operating motors, these common checks would be for abnormal temperature, abnormal noise, and abnormal vibration. Rather than explain the procedure each time in the write up for every subprocess in which a motor is used, common motor check instructions can be detailed in a separate subsection of the manual.

The next stage of the manual production process is information gathering. Depending on the technical background of the manual coordinator, some information gathering may be a necessary prerequisite to the process breakdowns previously described. Information can come from a variety of sources. General process descriptions can be derived from textbooks and manuals. For various subprocesses and pieces of equipment, descriptions and information on their operation can come from manufacturer's, designer's, and installer's documentation, from blueprints and specifications, from interviewing the operators who run the process and the maintenance personnel who service it, from the technical background of the author, and direct visual observation and operation of the equipment or process in question.

Information gathering can be a tedious process and can consume a fair amount of time. All the applicable personnel with information may not be available at any one time. They may need to be requestioned about certain points that crop up when the gathered information is analyzed. For older facilities, documentation in the form of blueprints, specifications and written instructions may be difficult to obtain, nonexistent, or, if changes have occurred, outdated.

The next steps in manual production consist of information analysis, organization, and synthesis. These are, without doubt, the most crucial steps of the entire process. As previously discussed, information comprehension and application by the end user are the goals that have to be met. Any information gathered will be totally useless if it is not analyzed, organized, and synthesized into a form that will make these goals possible. Information analysis can be thought of as an editing procedure. All of the information gathered must be examined to determine what is essential and what is extraneous. The extraneous information is discarded while the essential information is organized and put into a logical order or sequence. Finally, within a formatted framework, the organized information must be synthesized or written down into a coherent structure that will minimize the effort required for the retrieval of the information.

These steps are inter-related in that feedback can be employed at every step to alter previous steps. For example, synthesizing the information can result in a requirement to reorganize it. Similarity, organizing the information may bring to light more material that can be considered extraneous or which should be included.

Manual Characteristics

How information is analyzed, organized, and synthesized into a workable operations manual will depend, to a large extent upon the facility in question, the primary end uses of the manual, and the training, outlook and preference of the manual coordinator. Given a specific subprocess or operation however it is suggested that its intended manual documentation include the following:

a. the principle or rational behind the subprocess or operation, how it fits into a particular treatment process, or, on a higher level, how a particular treatment process fits into an overall treatment scheme;
b. what equipment is required for the operation;
c. where that equipment is location;
d. which personnel are responsible for conducting the operation;
e. when, or under what conditions must the operation be conducted;
f. how, in step by step detail, is the operation to be conducted;
g. what special precautions must be taken in carrying out the operation;
h. what observations must be made in carrying out the operation; and
i if information is obtained, how is it to be recorded, and/or what other use is to be made of it.

If the information to be conveyed contains all of the foregoing, it can be judged to be fairly complete. To minimize the effort required to retrieve it however, it is also suggested that the form (i.e., the written product) the information takes must have the following characteristics:

a. accuracy - the writing should be precise and scrupulously exact in detail;
b. clarity - the meaning of the instructions must be clear. No ambiguities and implications from which false interferences may be drawn should be allowed. Clarity may be achieved through the use of plain, concrete words and short, simple sentences. Information in bite-size chunks, as it were;
c. brevity - consistent with clarity, the instructions given should be as concise as possible.
d. revelance - only those instructions pertinent to the topic at hand should be expressed. Digressive, extraneous and redundant material will impede the expression of the subject matter and should be avoided. This characteristic may be imparted in analyzing and organizing date;
e. logic - instructions given should be in an orderly sequence such that each individual step proceeds naturally from the previous one and is a necessary prerequisite for the following one; and
f. interest - material provided should stimulate the intended user and hold his attention.

These characteristics can be imparted to the information to be conveyed through the choice of writing style, language, and format. These must be geared to the audience for whom the information is intended. For ease of information digestion, it is suggested that the language used for an operations manual should not be identical to that used for a paper in a research journal. Similarly, while precision and accuracy in the writing are desirable qualities, the grammar required in an operations manual would not be so precise and accurate as for a construction or patent specification. All of this is not to suggest that a manual should be written down to the users level. The information retrieval process becomes impaired, possibly irreversibly, once it is perceived by the end user that someone is trying to write down to him. What is required instead is simply a natural and smooth flowing writing style, aimed precisely at imparting to the information to be conveyed those characteristics mentioned above. Visual interest and clarity can also be imparted to the information by a clean, uncluttered layout and by presenting some of it, where appropriate, in the form of graphs, drawings, charts, tables, and figures.

Manual Applications

Having discussed how an operations manual can be put together and what it should contain, the following section offers suggestions on what it can be used for. If properly written and laid out, a manual can serve a number of purposes:

a. it can allow for a standardization of procedures. For smaller facilities with few staff, all of whom are thoroughly familiar with the operation, this factor may be of minimal importance. Where a larger facility, with shift work or high staff turnovers is involved, however, reproducible results or a uniformity of product may be dependent upon having standard procedures which are followed by all personnel. Examples of this that come readily to mind include the use by many laboratories of the analytical techniques (or variations thereof) listed in Standard Methods For the Examination of Water and Wastewater. In order for a laboratory to obtain results that can be reproduced by any technician or laboratory or that can be compared to previous results, everyone involved in the analysis must use the same standard test procedures. Another instance where a standardization of procedures can affect performance deals specifically with the Gold Bar Wastewater Treatment Plant. A large percentage (roughly 2/3) of the plant's electrical consumption is required to run the aeration blowers for the secondary system. When switching over blowers to meet fluctuations in air demand, peak power demand charges can be incurred unless certain procedures are carried out. In the past, this has not always been done and the plant has been billed unnecessarily for electrical usage. A procedure is therefore being standardized for blower switchovers that should result in cost savings yet not adversely affect treatment performance;

b. an operations manual can serve as a reference for procedures that are only infrequently carried out and which are therefore subject to memory lapses. Usually at any facility, certain operations and procedures are only carried out annually or at even longer intervals. Examples at the Gold Bar plant include shutting down digesters and aeration tanks for cleaning. Examples at other facilities may include cleaning out a lagoon. The timing of these infrequent operations may also be such that the crew on whose shift the operations is to be done may never have had any previous experience at it. In such cases, rather than wasting time trying to remember or figure out how it was done in the past, and possibly making a number of mistakes or safety violations in the process, easy reference can be made to an operations manual in which the procedure is detailed;

c. an operations manual can be used as a vehicle for training new personnel in the operation of the facility of process. In the current economic climate, staff turnover is not as great a problem as it has been in the past. Nevertheless, due to personnel retiring or leaving for various other reasons, new operators are taken on, and once taken on, they must be trained. Training would be expedited if reference can be made to a manual in which proper methods and procedures are detailed. This would be especially useful if, as at the Gold Bar plant, training of new operators is carried out by a variety of personnel on different shifts; and

d. finally, if kept updated, an operations manual can be used as a vehicle for training or acquainting personnel in new operating procedures. In an operation which remains static for long periods, this function may be of minimal importance. At many facilities (such as the Gold Bar plant), however, process optimization is a continuous ongoing process. This can create some confusion when changes in procedures or equipment are initiated and complete on one shift without the proper documentation to train or even acquaint the subsequent shifts or short term replacement personnel of the changes. Amendments properly issued and integrated into an operations manual can be used to largely overcome the confusion and assure a smooth continuity of operation.

Manual Updating

In a treatment facility, process optimization should be an ongoing process. An operations manual can therefore never be really considered complete because of the constant revision and amendments that would be required to keep pace with active operations and maintenance personnel changing various procedures and pieces of equipment. These manual revisions and amendments cannot be ignored. They must be made if the manual is to continue to accurately reflect the facility it purports to describe.

A regular updating program should therefore be considered an essential part of any manual production process. The Gold Bar plant is in a, perhaps unusual position of having equipment and procedure changes almost constantly occurring. While this undoubtedly can have positive treatment benefits, it can also create difficulties with keeping an operations manual current. Sections of the manual can become outdated soon after they are written. This is a problem which has not been fully resolved yet, but strategies are being examined, (such as using word processing equipment) to expedite the manual production process.

Example

For illustrative purposes, some specific material from the Gold Bar operations manual will now be examined. These may be taken as examples of how a specific manual might be put together. What may work for Gold Bar may not, of course, work for other facilities. As facilities vary, so will their manuals.

For ease of reference, the Gold Bar manual is divided into eight parts. These parts are separated along process lines. Part A of the manual is a general preface in which the manual is introduced, its format is outlined, and personnel, crews and shifts are designated.

An organization chart of the Wastewater Treatment Section is also presented. Figure 1 shows the Table of Contents of the general preface while Figure 2 shows the first page in which the manual is introduced and its aim, scope, and limitations are outlined.

Figure 3 shows part of the Table of Contents for Part D (Secondary Process) of the manual. This illustrates how processes may be further broken down into subprocesses and then individual operations.

Figure 4 reproduces an illustration from Part D that shows where all the various tanks and buildings involved in the Secondary Process are located.

FIGURE 1

ORGANIZATION
OF
GENERAL PREFACE

PART A - GENERAL PREFACE

TABLE OF CONTENTS

INTRODUCTION
    Aim and Scope
    Manual Format

PERSONNEL
    Designation of Crews
    Designation of Personnel
    Shift Designation

ORGANIZATION

LIST OF FIGURES

FIGURE	LIST
A - 1	Wastewater Treatment Table of Organization

FIGURE 2

MANUAL INTRODUCTION, AIM, SCOPE and LIMITATIONS

INTRODUCTION

Aim and Scope

1. The aim of the enclosed manual is to provide detailed instructions for the routine operation of all the wastewater treatment facilities operated by the City of Edmonton. As these instructions will primarily be carried out by the shift and spare crews, no instructions are provided for other plant functions such as facilities maintenance and laboratory analysis. In areas, such as sampling, where the latter functions interface with routine plant operations, instructions applicable to those operations are also provided.

2. Many emergency operating procedures are also not covered in the manual, as it would not be practical to write detailed instructions for every conceivable nonroutine situation. As in the past, the operating response to these circumstances will continue to depend, to a large extent, upon the experience and judgement of the individual foreman, and, in some cases, the Director of Operations. This policy will also apply for items of scheduled or emergency maintenance.

3. As the running of the plant is not a static operation, and facilities optimization is an ongoing process, it is expected that circumstances will dictate changes in the operating procedures set down in the manual. Manual amendments will therefore be issued accordingly.

FIGURE 3

PROCESS BREAKDOWN

PART D - GOLD BAR SECONDARY PROCESS

TABLE OF CONTENTS

INTRODUCTION

- General
- Principles
- Gold Bar Process Description and Flow
- General Responsibilities

SECONDARY BYPASS

- General
- Procedure

PE FEED CONTROL

- General

PROCESS CONTROL TESTS

- General
- Settled Volume Test
- Clarity Test

SECONDARY SAMPLING

- Pipe Gallery Sampling
- PEC Sampling

SECONDARY SCUM

- Introduction
- Scum Handling - Sections 1 to 5
- Scum Handling - Sections 6 to 8

RETURN ACTIVATED SLUDGE

- Introduction
- RAS - Sections 1 to 5
- RAS - Sections 6 to 8

WASTE ACTIVATED SLUDGE

- Introduction
- WAS - Sections 1 to 5
- WAS - Sections 6 to 8

FIGURE 4

PROCESS LAYOUT

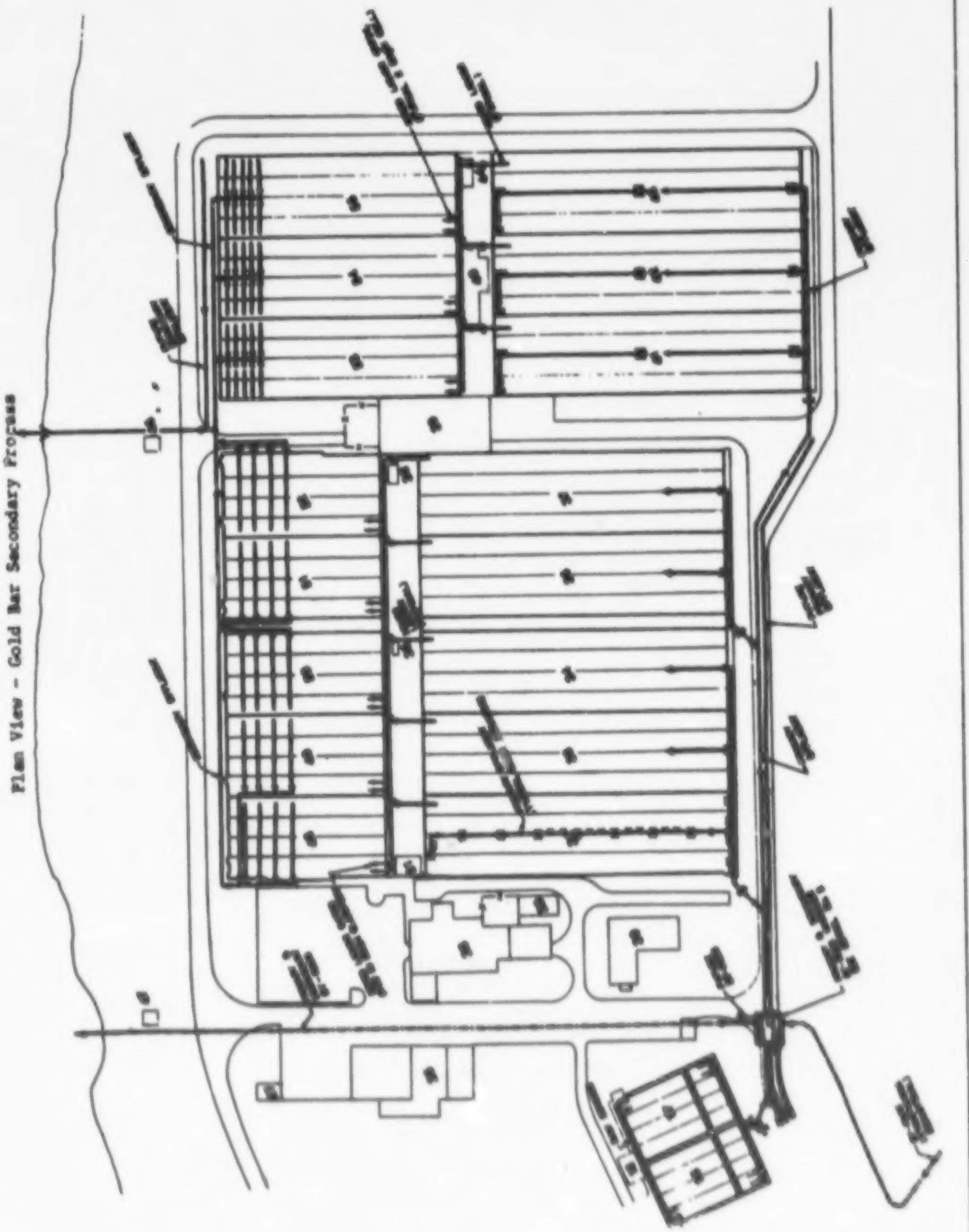


Figure D-5

Plan View - Gold Bar Secondary Process

FIGURE 5

BREAKDOWN OF
RESPONSIBILITIES AND DUTIES

Responsibilities

1. Shift Crew. In the screening process, shift crew personnel will be responsible for:

   a. keeping the screening mechanism free of debris and adjusting the rake speeds as required on manual operations;
   b. operating the screen hoists, and dumping and cleaning the screen collection buckets as required;
   c. operating the conveyor belt in Screen Building 2 and periodically levelling out the load in the screening truck as required;
   d. maintaining the screen building interiors (equipment, walls and floors) in a clean, orderly manner; and
   e. monitoring the screening process for signs of abnormal operation and providing the attendant Trouble Reports as required;

2. Relief Crew. In the screening process, personnel in the relief crew will be responsible for:

   a. operation of the screening truck;
   b. flushing and cleaning of the same after its use;
   c. dumping and cleaning of the screen collection buckets as required; and
   d. operation of the interlock controller in Screen Building 1.

FIGURE 6

EXPLANATION OF PROCEDURE

Primary Sampling

1. Sampling of primary sludge is required for process control and instrument calibration purposes. In order to be of any use however, the samples obtained must be as representative as possible of the primary sludge pumped to the digestors. To obtain representative samples of primary pumping, sampling will be carried out during every second pumping sequence therefore, every second sequence will be sampled, and for double pumping sequences, every second sequence will be completely (i.e., both the first and second pumping) sampled.

2. During each 15 minutes pumping sequence from Primary Clarifiers 1, 2 and 5 to 8 for which sampling is required, sampling will be carried out:

   a. once at three minutes after the start of the pumping sequence;
   b. once near the middle of the pumping sequence; and
   c. once at three minutes from the end of the pumping sequence.

3. For Primary Clarifiers 3 and 4, for a pumping sequence for which sampling is required, one sample per sludge hopper per 15 minute sequence must be obtained. Each sample is to be taken at the midpoint of the pumping from the hopper in question

4. A 100 mL sample cup and container bucket is provided at each sample station. For Primary Clarifiers 1 and 2, the sample stations are located in the tunnel adjacent to the sludge pump gallery, while for Primary Clarifiers 3 and 4, a sample station is co-located with each set of sludge pumps. There is only one sample station serving Primary Clarifiers 5 to 8 and this is located in Tunnel C.

5. A standardized sampling procedure is set out in Table B-11. Each 24 hour sample period will commence at 0800 on the day indicated. At the end of the period, i.e., at the end of the night shift, the contents of each sample bucket must be thoroughly mixed and poured (3/4 full for easy laboratory mixing) into the sample container provided.

FIGURE 7

DETAILED PROCEDURE INSTRUCTIONS

Table B-11

Standardized Primary Sampling Procedure

Step	Procedure
1	Wet down the sample sink (a).
2	Turn on the sample line (b).
3	Once the line has been purged and sludge is flowing freely from it, fill the 100 ml sample cup and deposit the contents into the bucket provided.
4	Close off the sample line.
5	Clean off the sink and the sample cup with water from the potable water line.
6.	Flush out the sample line with potable or FE water, whichever is available.
7	Between pumping sequence, store the sample bucket in the refrigerator if one is available.

NOTES: (a) This will enable an easier cleanup of the sample sink.

(b) This will involve turning on the discharge line on both the main pipe manifold and the sample line in question. Samples from Primary Clarifiers 1 and 2 will be taken from the suction line to the sludge pumps while samples from the remaining tanks will be taken from the sludge pump discharge lines. This will be the lowest inflow line valves on the pipe manifold for the Primary Clarifiers 1, Primary Clarifiers 3 and 4.

FIGURE 8

DIAGRAM OF EQUIPMENT CONTROLS

Figure D-15
Typical Automatic DO Controller

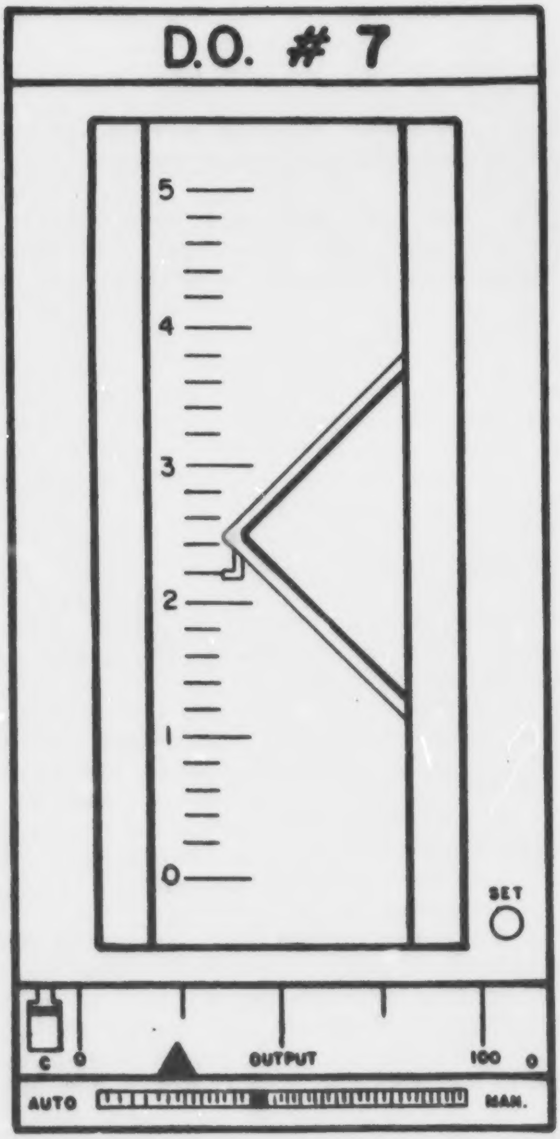

D.O. # 7
5
4
3
2
1
0
SET
C
O
OUTPUT
100
O
AUTO
MAN.

Figure 5 shows, for a particular subprocess, how responsibilities may be broken down and delegated. Figure 6 is a text page from the manual partially explaining how, why, when and where a particular operation, in this case, primary sampling, is to be carried out. For ease of reading, 1 1/2 spacing has been adopted for test material with paragraphs numbered and separated from each other. Figure 7 shows the table that accompanies the explanatory test on primary sampling. The table details the step by step instructions that are required, to carry out the operations.

Finally, Figure 8 gives illustration of some controls at the Gold Bar plant. In addition to process schematic diagrams, control panel illustrations are often useful accompaniments to explanatory material on how to operate a particular piece of equipment or control or monitor a particular process.

Summary

In summary, some material has been presented on operations manuals, how they can be produced, what information they should contain, and what they can be used for. Illustrations on how a particular operations manual, currently being produced, is organized have also been presented.

Hopefully this material has raised some interest amongst personnel working at facilities without an operations manual and contemplating one or has brought out some points that may not have occurred to personnel at facilities already with one. If either has occurred, the purpose of this paper has been fulfilled.

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ON-LINE MONITORING OF CHLORINE DIOXIDE AT CITY OF EDMONTON ROSSDALE WATER TREATMENT PLANT

Milton J. Tkaczyk, Chemist
Edmonton Rossdale Water Treatment Plan

Chlorine dioxide is a strong oxidant and disinfectant.

In the City of Edmonton Water Treatment Plants, chlorine dioxide is used to complement and not to replace chloramine treatment.

Chlorine dioxide treatment in the City's water treatment plants was first introduced in 1982. Its main use was for control of taste and odor that occurred during adverse raw water conditions such as spring run-off and during rainy periods. Rainy periods flush streets of oils and tars via upstream storm sewers into the river, which is the raw water supply.

Chlorine dioxide is now used year round for disinfection as well as taste and odor control. At first, the generation of chlorine dioxide ($2NaClO_2 + Cl_2 \quad 2ClO_2 + 2NaCl$), was done by bringing in powdered sodium chlorite in drums and from that, making a 25% solution which was reacted with chlorine to produce chlorine dioxide.

Now a local supplier prepares the sodium chlorite solution on their own site and delivers it in a liquid form, by tanker trucks, to on-site storage tanks at each plant (tanks hold approx. 6000 litres).

The City has five chlorine dioxide generating systems at its plants. It has three different types of on-line chlorine dioxide residual analyzers. All the generators work on the same principal. Two of the analyzers are amperometric chlorine analyzers. The buffers were altered and the analyzers were calibrated to measure chlorine dioxide. The other analyzer is a colorimetric on-line chlorine dioxide-chlorite analyzer.

The whole system consists of a chlorine dioxide generator, a chlorine metering system, a sodium chlorite feed system and the on-line residual analyzer.

Due to the importance of accurate chemical feed, a high and a low feed rotameter for chlorine was installed. This gave a very accurate chlorine feed rate when low amounts were needed.

The sodium chlorite is fed through a micro motion-mass flow meter which measures the amount of sodium chlorite in grams/minute. This system has a calibration method to check if proper feed rate is applied.

The sodium chlorite and the chlorine are fed through the reaction column to produce chlorine dioxide. The reaction column is constructed in such a way as to give maximum contact area and time so as to complete the chemical reaction to form chlorine dioxide before entering into the educator stream. This educator stream feeds the water treatment process with a required chlorine dioxide dosage.

A certain dosage of chlorine dioxide is applied in the treatment process, but the important aspect of this treatment is to meet the demand. This involves monitoring continuously the amount of chlorine dioxide remaining, if any. With this determination dosage adjustments can be made.

These chlorine dioxide residual determinations are made by using on-line amperometric analyzers, using a pH 7.0 buffer to which potassium iodide has been added. The analyzer itself is calibrated to a chlorine dioxide standard which is prepared in accordance with "Standard Methods for the Examination of Water and Wastewater".

In all cases, the sample to be measured must be obtained before the addition of chloramines as these will be measured as chlorine dioxide if present. The sample is run through the analyzer and the residual chlorine dioxide is measured and recorded on a 24 hour chart, giving operations personnel a continuous residual readout. This system is equipped with a high-low alarm warning bell. Being located in the control room, this alarm makes the operator aware of a high or low chlorine dioxide residual. Feedrates are then adjusted to meet the required residual levels.

The colorimetric chlorine dioxide-chlorite analyzer measures the color intensity of a reactant chemical, with chlorine dioxide, in the chlorine dioxide analyzer. A slightly different reactant chemical is used to measure chlorine dioxide and chlorite in the chlorite analyzer system. This color intensity is higher due to both the chlorine dioxide and chlorite species measured.

After a predetermined reaction time (10 minutes) the chlorine dioxide is measured and recorded on a digital readout as mg/L ClO_2. After the same reaction time the chlorine dioxide-chlorite is also measured, but in this case the chlorine dioxide from the first analyzer is internally subtracted from the total in the chlorine dioxide-chlorite to give a digital chlorite readout in mg/L ClO_2^-.

More work has to be done on the measurement of the chlorite as the monitoring of residual chlorine dioxide was the focal point.

The suppliers of sodium chlorite will provide safe handling procedures for sodium chlorite and chlorine dioxide.

Supplementary notes to presentation given on Friday, March 8, 1985 at the Alberta Water and Wastewater Operators' Association Seminar, Banff, Alberta.

by
Milton J. Tkaczyk
and
George S. Walker

I Chemical Characteristics

The industrial form of chlorine dioxide (ClO_2), a yellow gas, is sodium chlorite ($NaClO_2$), a white crystalline solid.

If ClO_2 gas reaches a concentration of 10% in air, a spark or shock could detonate it. At 1.5% concentration in air ClO_2 is just perceptible to the nose (pungent, similar to smell of chlorine gas). A 5% concentration in air irritates the mucous membranes. Toxicity to animals and man in air is comparable to that of chlorine gas. Pure ClO_2 in neutral aqueous solution is very stable in the dark.

ClO_2 cannot be transported because it is too unstable and is therefore generated at the point of usage from $NaClO_2$ and chlorine.

ClO_2 is generated in aqueous solution so that the gas is never out of solution as far as humanly possible. In solution it presents virtually no risk to operating personnel.

100% pure sodium chlorite ($NaClO_2$), the chemical salt used to generate ClO_2 gas in solution, is met only rarely in the laboratory. It is too dangerous to use in pure form. It will explode if heated to 180°C, subjected to any violent shock, or brought into contact with organic materials.

Technical $NaClO_2$, marketed for industrial purposes like water treatment, never exceeds 80% purity for safety reasons. The remaining 20% is made up variously with mixtures of sodium carbonate, chlorate, chloride and silicate. The 20% balance is preferably mostly sodium retardant and anti-caking agent. For water treatment purposes alkalinity should be kept to a minimum range of 11 to 13 g/L (as $CaCO_3$). Higher alkalinities retard conversion to ClO_2.

For a water plant operation it is safer and more efficient to purchase $NaClO_2$ in water solution of 25%, thus avoiding handling of the more dangerous solid material.

Accidentally spilled (or leaked) $NaClO_2$ solution should be cleaned up immediately by swilling the area with water. If allowed to dry, the white crystalline residue is a fire hazard and can be ignited into a violently burning mass by a single static electricity spark.

II Generation

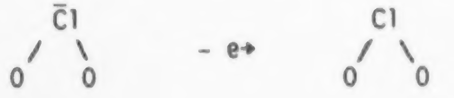
Generation is simple in theory, $NaClO_2$ in aqueous solution is dissociated as sodium ions (Na) and chlorite ion (ClO_2^-). By contrast, ClO_2 does not dissociate in water after it is formed and resides unaltered in solution until such time as it enters into reaction (oxidation) with some other constituent also present in the water.

The key to understanding generation of ClO_2 and its subsequent reaction in water lies in understanding the basic principles of reduction and oxidation.

Oxidation is the removal of an electron or electrons from the chemical entity being oxidized (removal of negative charge).

Reduction is the addition of an electron or electrons to the chemical entity being reduced (addition of negative charge; it is easy to remember that REDUCTIONS = REDUCING THE CHARGE).

Removal of an electron (symbol e) from the chlorite ion (group of 2 atoms with a negative charge) to produce a molecule of the same 3 atoms, lacking any electronic charge, is the formation of chlorine dioxide:



ClO_2^- chlorite

ClO_2 chlorine dioxide

The oxidant used is chlorine gas. It oxidizes the chlorite by removing an electron.

$$2\ NaClO_2 + Cl_2 = 2\ ClO_2 + 2\ NaCl$$

or simply

$$NaClO_2 + Cl = ClO_2 + NaCl$$

$$90.46 + 35.46 = 67.46 + 58.46$$

The formula weights of chemical species involved indicate that every 67.46 weight units of ClO_2 produced required 90.46 weight units of $NaClO_2$ and 35.46 weight units of chlorine (refer to description of use of operators' charts below). The weights of $NaClO_2$ (g/min) indicated for the operator's use are not the same as those indicated above, but are corrected to allow for corresponding weights of $NaClO_2$ in solution, as fed to the generator.

III Advantages of ClO_2 Treatment

Will oxidize many types of organic compounds which give rise to taste and odor complaints, ClO_2 is a more efficient disinfectant than chlorine.

IV Limitations

Treatment with ClO_2 will not eliminate taste and odor problems resulting from contamination of the water supply by petroleum-derived organic compounds (gasoline, diesel fuel, oil, solvents, etc.).

V Yield Determination

An example from recent operation at Rossdale W.T.P. (Nos. 1 & 2) of yield determination by laboratory staff, subsequent adjustment of chemical feed, and follow-up yield determination to verify improvement - all within one hour:

$$Y = \%\text{ of } NaClO_2 \text{ actually converted to } ClO_2$$

$$= \frac{[ClO_2]}{[ClO_2] + [ClO_2{}^-]} \quad ;$$

brackets indicate concentrations found in generator output stream (mg/L).

First Det'n: $\dfrac{2.5.8}{205.8 + 34.6} = 85.6\%$

Second Set'n $\dfrac{221.2}{221.2 + 27.4} =$

FIGURE 1

Fig.1 FLOW RATE VERSUS TIME DELAY BETWEEN CHLORINE DIOXIDE INJECTION & ON-LINE MONITORING ROSSDALE PLANT No. 3 - CITY OF EDMONTON

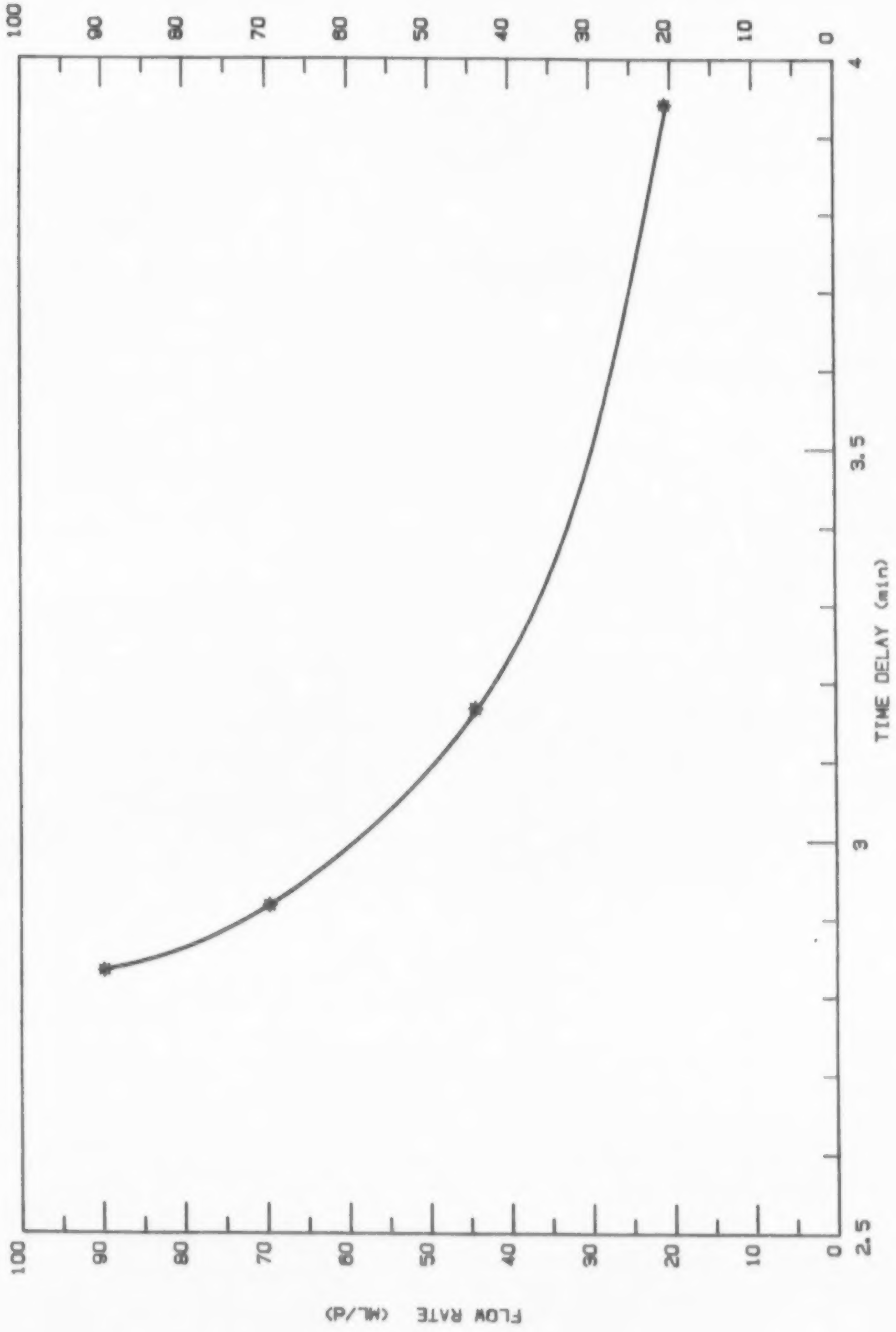
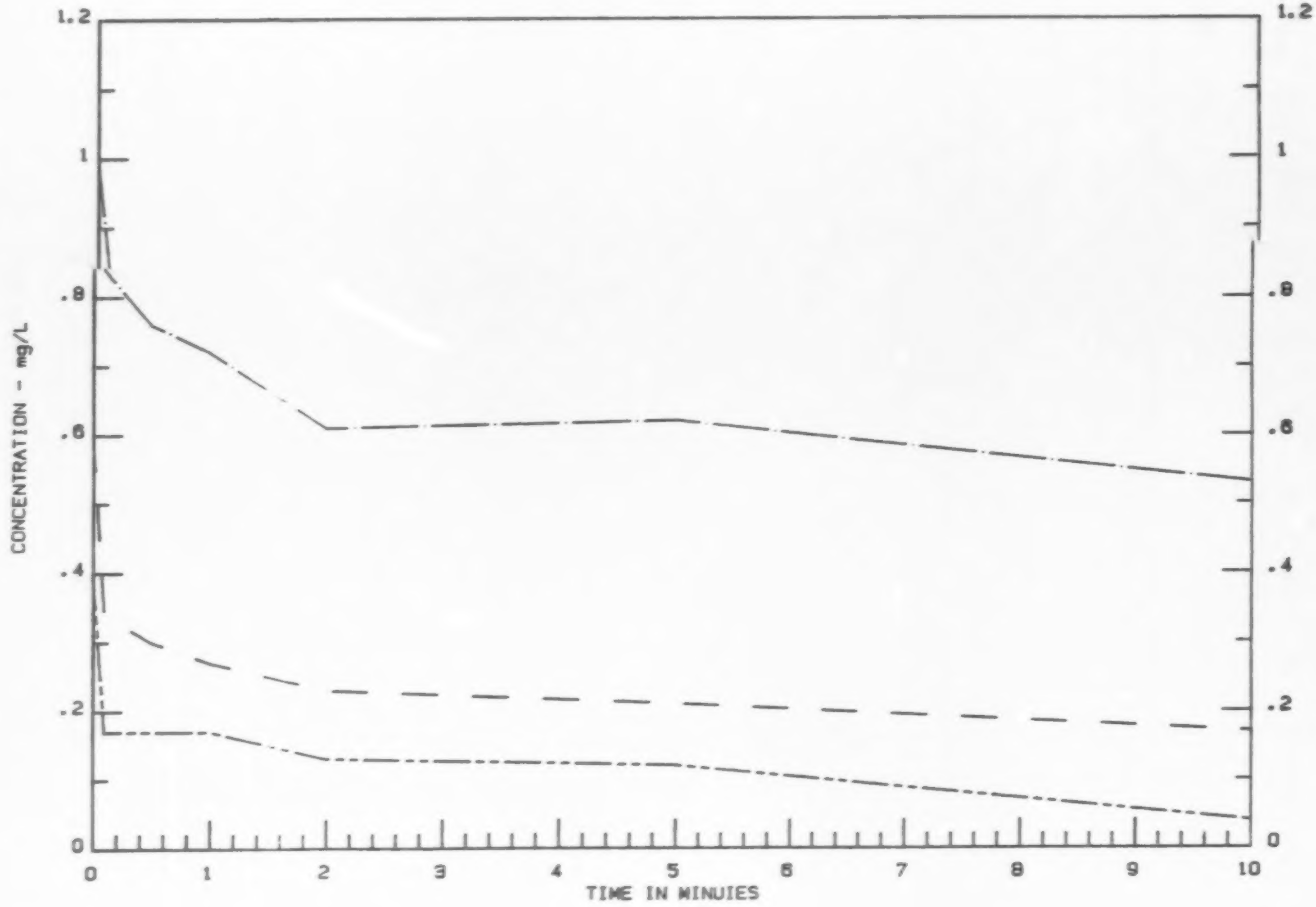


Figure 2

Fig. 2 CHLORINE DIOXIDE DEMAND TEST ON RAW WATER
ROSSDALE PLANT - CITY OF EDMONTON
SEPTEMBER 25/85



CHLORINE DIOXIDE DEMAND TEST ON RAW WATER AT ROSSDALE NO. 3 W.T.P., EDMONTON
SEPTEMBER 25, 1984,
UNDER CONDITIONS OF MODERATE POLLUTION
(Downstream from Storm-sewer outfalls; no precipitation)

ime Zero lO_2)se	After 10 Sec		After 30 Sec		After 1 Min		After 2 Min		After 5 Min		After 10 Min	
	Res/ Dem	% Con	Res/ Dem	% Con	Res/ Dem	% Con	Res/ Dem	% Con	Res/ Dem	% Con	Res/ Dem	% Con
40	0.17/ 0.23	58%	0.17/ 0.23	58%	0.17/ 0.23	58%	0.13 0.27	68%	0.12 0.28	70%	0.04/ 0.36	90%
60	0.34/ 0.26	43%	0.30/ 0.30	50%	0.27/ 0.33	55%	0.23/ 0.37	63%	0.21/ 0.39	65%	0.17/ 0.43	72%
00	0.84/ 0.16	16%	0.76/ 0.24	24%	0.72/ 0.28	28%	0.61/ 0.39	39%	0.62/ 0.38	38%	0/53. 0.47	47%

O_2 dose, residual and demand in mg/L (ppm); raw water temp - 12°C at time zero;
:s - Residual; Dem - Demand; % Con - % Consumed

CHLORINE DIOXIDE DEMAND TEST ON RAW WATER AT E.L. SMITH W.T.P. EDMONTON
FEBRUARY 6, 1985,
UNDER CONDITIONS OF MODERATE POLLUTION
(Downstream from Storm-sewer outfalls and prior to spring runoff)

me Zero O_2)se	After 5 min		After 30 Min		After 1 Hr		After 2 Hr.		After 4 Hr.		After 6 Hr.	
	Res/ Dem	% Con	Res/ Dem	% Con	Res/ Dem	% Con	Res/ Dem	% Con	Res/ Dem	% Con	Res/ Dem	% Con
12	0.00/ >0.12	100%	0.00/ >0.12	100%	ND		ND		ND		ND	
23	0.09/ 0.14	61%	0.05/ 0.18	78%	0.02/ 0.21	91%	0.01/ 0.22	96%	0.00/ >0.23	100%	ND	
35	0.16/ 0.19	54%	ND		0.09/ 0.26	74%	0.03/ 0.32	91%	0.00/ >0.35	100%	ND	
46	0.25/ 0.21	46%	ND/		0.15/ 0.31	67%	0.10/ 0.36	78%	0.07/ 0.39	85%	0.03/ 0.43	93%
58	0.34/ 0.24	41%	ND		0.21/ 0.37	64%	0.14/ 0.44	76%	0.10/ 0.48	83%	0.09/ 0.49	84%
69	0.42/ 0.27	39%	ND		0.31/ 0.38	55%	0.25/ 0.44	64%	0.21/ 0.48	70%	0.11/ 0.58	84%

O_2 dose, residual and demand in mg/L (ppm); raw water temp - 18°C at time zero, 20°C
'ter 6 hr; ND - Not determined; Res - Residual; Dem - Demand; % Con - % Consumed

Figure 3

Fig. 3 CHLORINE DIOXIDE DEMAND TEST ON RAW WATER
E.L. SMITH PLANT - CITY OF EDMONTON
FEBRUARY 6/85

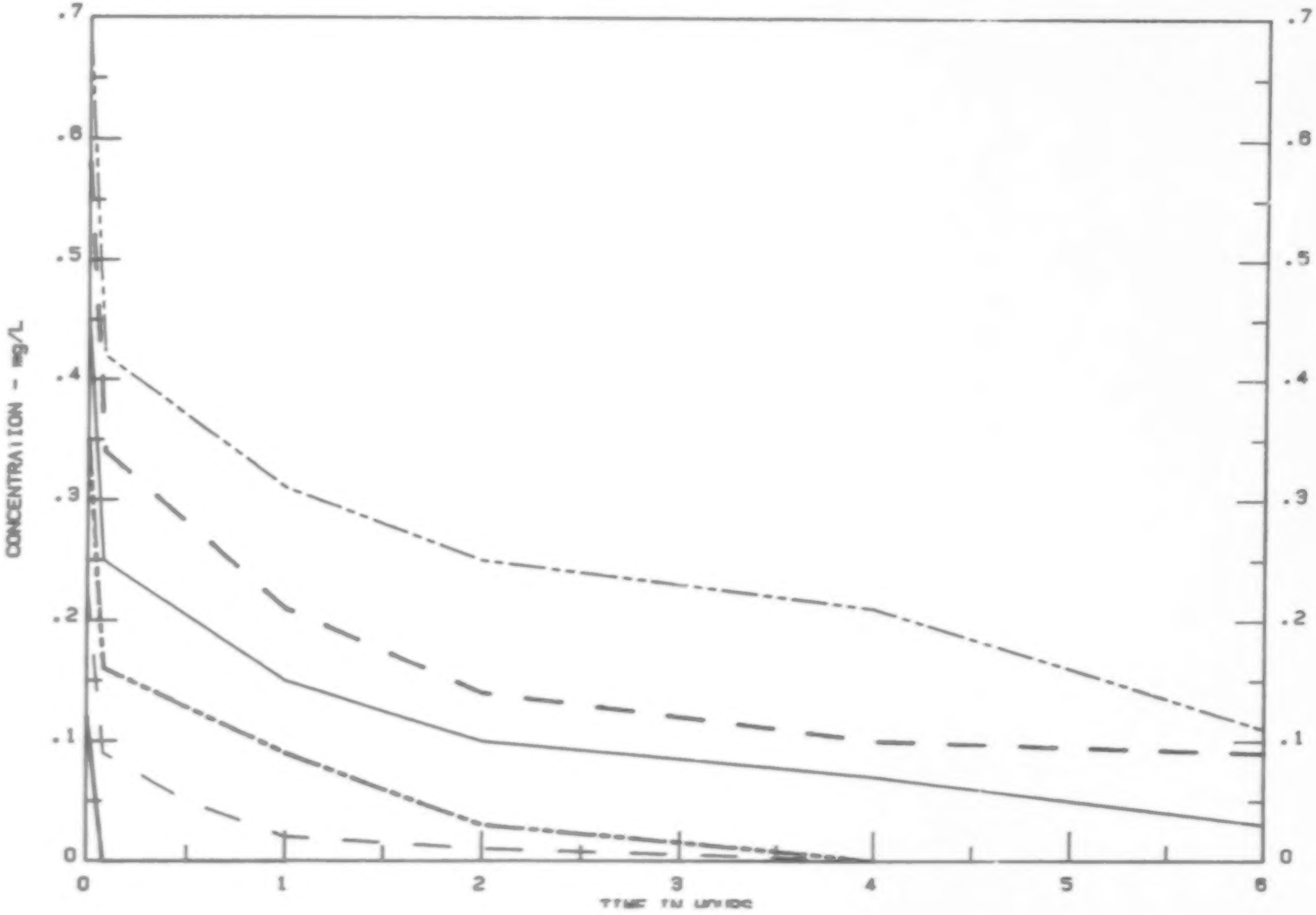
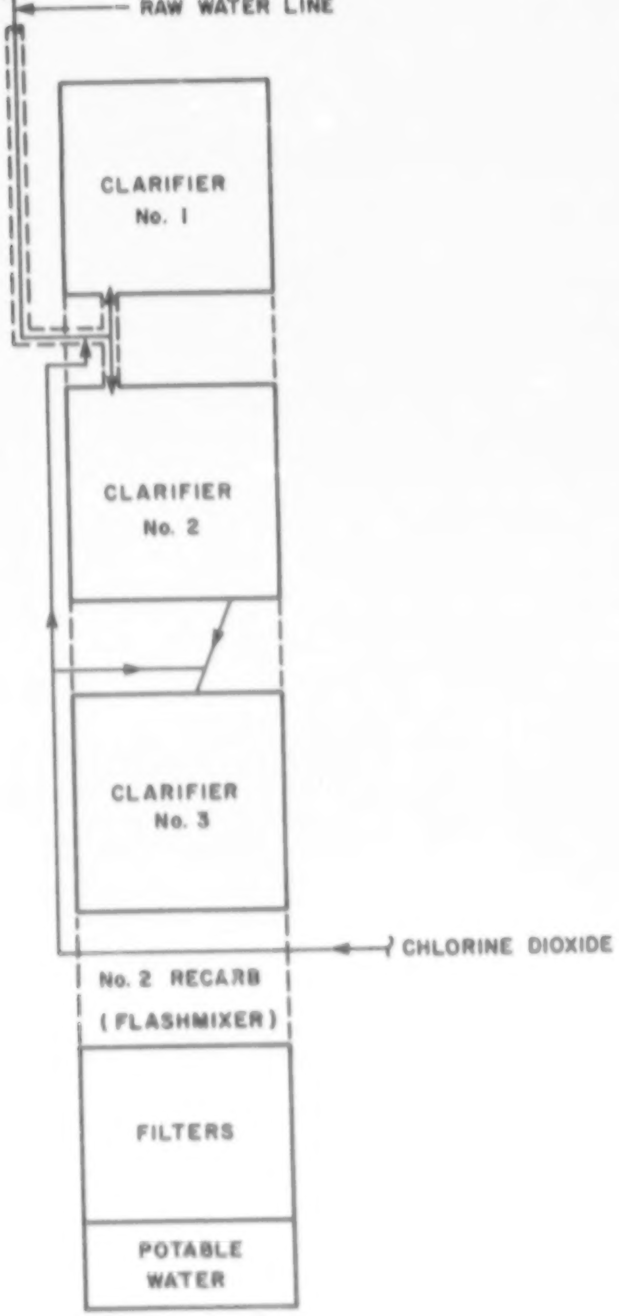
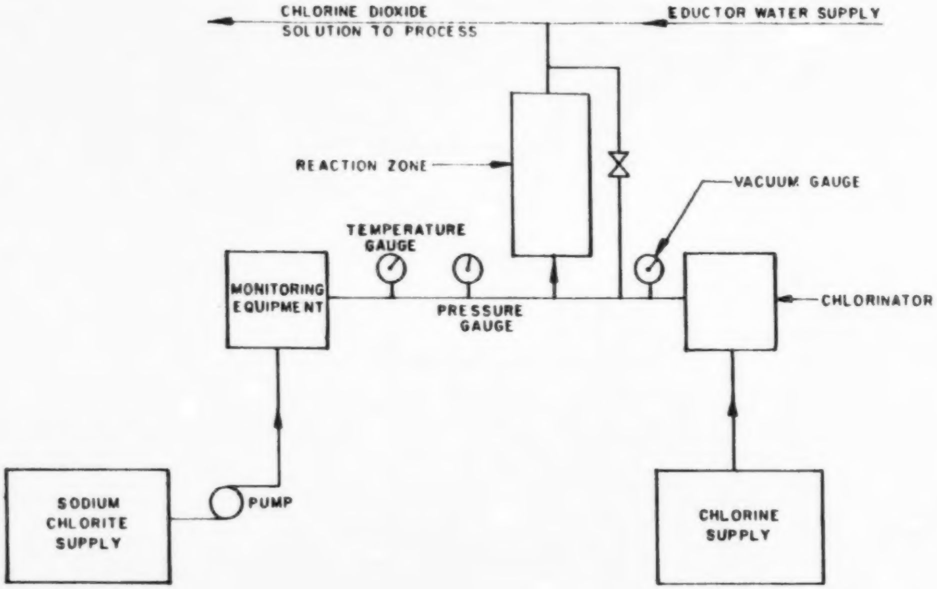


Figure 4


RAW WATER LINE
CLARIFIER No. 1
CLARIFIER No. 2
CLARIFIER No. 3
CHLORINE DIOXIDE
No. 2 RECARB
(FLASHMIXER)
FILTERS
POTABLE WATER

CHLORINE DIOXIDE APPLICATION POINTS
E.L. SMITH WATER TREATMENT PLT. # 4

Figure 5


CHLORINE DIOXIDE
SOLUTION TO PROCESS
EDUCTOR WATER SUPPLY
REACTION ZONE
VACUUM GAUGE
TEMPERATURE GAUGE
MONITORING EQUIPMENT
PRESSURE GAUGE
CHLORINATOR
SODIUM CHLORITE SUPPLY
PUMP
CHLORINE SUPPLY

CHLORINE DIOXIDE GENERATION SCHEME

SELECTION OF CHEMICAL FEEDRATES FOR ClO_2 GENERATION

Chart 1

ClO_2 Feedrate   Purpose: To determine required ClO_2 feedrate.

Input Info.

Item 1: Pumpage (ML/d H_2O)
Item 2: Desired ClO_2 dosage (mg/L = ppm)

Output Info.

Item 1: ClO_2 feedrate requirement (kg/h)

Chart 2

Feedrates of two ClO_2 Generation Chemicals

Purpose: To determine feedrate settings of two stock chemicals necessary to operate ClO_2 generator.

Input Info.

Item 1: ClO_2 feedrate (kg/h) from Chart 1.

Output Info.

Item 1: Required sodium chlorite feed setting (g/min)
Item 2: Required Cl_2 gas feed setting (kg/h or lb/d)

Example of Use:

The No. 3 Plant operator needs to know sodium chlorite and chlorine gas settings required to feed 0.5 ppm ClO_2 while pumping 82 ML/d.

With Chart 1 he finds ClO_2 feedrate of 1.7 kg/h ClO_2.

Turning to Chart 2 (reading from left to right) he finds at this feedrate (1.7 kg/h ClO_2) that 158.7 g/min of 25% $NaClO_2$ and 49 lb/d (or 0.93 kg/L) of chlorine gas are needed to run the generator at the desired rate.

PROCEDURES & RECOMMENDED WORK PRACTICES FOR SERVICE CONNECTIONS ON PVC/C900 PIPE

T.R. Roulston,
Canadian Technical Pipe Representative
Manville Canada Inc., Edmonton

Service connections vary in size from small services supplying individual homes to large outlets for industrial users. Service lines are connected to PVC water mains using the following methods:

- Tapping through service clamps or saddles
- Tapping sleeves and valves for larger service connections, and
- Direct tapping (AWWA C900 PC 150 and PC 200 only, 3/4 - and 1 - in. corporation stops).

Service Clamps or Saddles

Service connections may be made using a service clamp or saddle. Maximum outlet size recommended with service clamps or saddles is 2 in. (50 mm) When making this type of connection with the line under pressure, equipment is used which attaches to the corporation stop and permits a cutting tool to be fed through the corporation stop to cut a hole in the pipe. Cutting tools should be sharp and should not apply excessive pressure. No threading of the pipe wall is required since the corporation stop is threaded into the service clamp. Service clamps or saddles used with PVC water pipe should:

- Provide full support around the circumference of the pipe, and
- Provide a bearing area of sufficient width along the axis of the pipe, 2 in. (50 mm) minimum, ensuring that the pipe will not be distorted when the saddle is tightened.

Service clamps should not:

- Have lugs that will dig into the pipe when the saddle is tightened.
- Have a U-bolt type of strap that does not provide sufficient bearing area, or
- Have a clamping arrangement that is not fully contoured to the outside diameter of the pipe.

A number of tapping machines are available that will drill through a corporation stop. It is important that the cutting tool be a shell-type cutter (hole cutter) that will retain the coupon and that is designed to accommodate walls as heavy as DR 14 (Pressure Class 200, AWWA C900). Many shell cutters are designed only for thin walled PVC; they do not have sufficient throat depth to handle the heavier walled pipe.

Service clamps and saddles should be installed in accordance with manufacturer's recommendations.

Tapping Sleeves and Valves

Tapping sleeves and valves are used when service connections larger than 2 in. (50 mm) must be made in PVC water main. Tapping sleeves may be used for making large taps under pressure.

When tapping sleeves are ordered from the manufacturer, the outside diameter of the pipe being tapped, the size of the outlet desired, and the working pressure should be specified to ensure that the sleeve furnished will be satisfactory. Lead-joint sleeves should not be used.

Tapping sleeves should be assembled in accordance with the manufacturer's directions. Drilling equipment can be purchased or rented from sleeve manufacturers, who will also furnish instructions and/or instructors trained in making such taps. (Contractors who specialize in this type of work are also available in some areas.)

Tapping sleeves should be well-supported independently from the pipe during the tapping. Support used should be left in place after tapping. Thrust blocks should be used as with any other fitting or appurtenance.

Recommended minimum lengths of tapping sleeves for the various main and tap sizes for AWWA PVC pressure pipe are listed below.

Minimum Tapping Sleeve Length

Main & Tap (in. nominal)	Minimum Laying Length	
	in.	mm
4 x 2, 4 x 3, 4 x 4	16	406
6 x 2, 6 x 3, 6 x 4, 6 x 6	18	457
8 x 2, 8 x 3, 8 x 4, 8 x 6	19	483
8 x 8	21	533
10 x 2, 10 x 3, 10 x 4, 10 x 6	19	483
10 x 8, 10 x 10	23	584
12 x 2, 12 x 3, 12 x 5, 12 x 6	19	483
12 x 8	21	533
12 x 10, 12 x 12	25	635

Direct Tapping

For some sizes of AWWA C900 PVC pipe, service connections may be made by the direct tapping of pipe wall and the insertion of a corporation stop. PVC pipe manufactured in accordance with AWWA C900 in nominal sizes 6 - 12 in. (150 - 300 mm), Pressure Classes 150 and 300, is being successfully direct tapped in the field. For 4 in. (100 mm) nominal size, Pressure Class 150 and 200, and for all sizes in Pressure Class 100, service clamps or saddles should be used. In direct tapping, proper use of specified direct tapping equipment, corporation stops, polytetrafluoroethylene (for example, Teflon) thread sealant tape, and a torque wrench is recommended. Do not use liquid thread sealants. This procedure should be used with proper direction and instructions from the manufacturer of the PVC pipe and the manufacturer of the direct tapping equipment.

Connecting Service Line

In common practice, service connections (service clamps, saddles, and direct taps) are installed with the outlet at an angle of 45° above horizontal. It is recommended that direct taps be placed on the cold climate regions, to prevent the service line from being appreciably closer to the ground surface than the water main. A bend, of "gooseneck," in the service line should always be provided to ensure flexibility and to accommodate the effects of load due to settlement, expansion, and/or contraction. Proper soil consolidation should be provided in the area of the service connection.

Direct Tapping Safety Precautions

When direct tapping any pressurized water pipe, (such as A/C, Iron, PVC pipe) basic safety precautions are advised to prevent personal injury. Regardless of the type of water pipe tapped, the following hazards should be considered in the event of complications experienced during the direct tapping procedure:

- Flying pieces of broken pipe or dislodged corporation stop;
- Flying debris dislodged by water impact;
- Direct water stream impact under pressure;
- Flooding of the trench;

Although the above complications may not be commonly experienced, the following safety procedures are recommended when direct tapping any pressurized water pipe:

1. Do not enter a trench or hole to perform direct tapping procedures without a second workman or supervisor present in the immediate vicinity to provide assistance if necessary.

2. Wear protective clothing including hard hat, goggles or face shield, gloves, safety shoes and heavy use pants and shirt.

3. Prepare a means of simple exit from the working area in the event of flooding. A sturdy ladder may be required.

4. The exposed pipe should be covered with a protective blanket (such as heavy, coarsely woven fabric) to dissipate the water stream and contain flying construction material or debris in the event of direct tapping failure. The protective blanket

should be at least 4 x 6 ft. in size and should have a hole in the centre to permit installation and operation of the tapping machine.

5. Use only tapping equipment, cutting tools, corporation stops and procedures recommended by the pipe manufacturer.

6. Insure that trench walls are properly supported by shoring, sheeting or trench box in accordance with accepted safety procedures and regulations if trench wall collapse could create hazard during tapping procedures.

The recommendations for servicing PVC water mains was taken from AWWA Manual No. M23; PVC Pipe - Design and Installation. The Direct Tapping Safety Precautions were drawn up by the National Utilities. Contractors Association and have been adopted by the PVC pipe industry.